Estimation of the Abundance of Chinook Salmon (*Oncorhynchus tshawytscha*) in the Upper Yukon River Basin Using Mark-Recapture Methods: 1990 – 1995

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ESTIMATION OF THE ABUNDANCE OF CHINOOK SALMON (*Oncorhynchus tshawytscha*) IN THE UPPER YUKON RIVER BASIN USING MARK-RECAPTURE METHODS: 1990 – 1995

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ABSTRACT

Johnson, Y., I. Boyce, and B. Waugh. 2002. Estimation of the abundance of chinook salmon (*Oncorhynchus tshawytscha*) in the upper Yukon River Basin using mark-recapture methods: 1990-1995. Can. Tech. Rep. Fish. Aquat. Sci. 2378: 98 p.

Fisheries and Oceans Canada (DFO) conducted mark-recapture studies on adult Yukon River chinook salmon from 1990-1995. Up to 2,174 upstream migrants were spaghetti tagged annually at two fishwheels located at the international border. Recaptures were made in a commercial fishery which harvested up to 12,028 fish and terminated more than 200 kilometres upstream. Pooled Petersen abundance estimates ranged from 41,187 to 56,679. Subtracting harvest, spawning escapement ranged from 20,743 to 37,699. Mean harvest rates for commercial, aboriginal, domestic and recreational fisheries were 23.8%, 15.8%, 0.6% and 1.3% respectively. Migration speed increased with distance from the tagging site. Specific spawning populations were enumerated but a significant relationship with mark-recapture data was not apparent ($p>.05$). In 1995, commercial catches were compared with DFO fishwheel catches; they comprised older and larger fish. Also in 1995, Schaefer, Darroch, and stratified Petersen estimators were compared with the pooled Petersen estimator and differed by less than 15%.

RÉSUMÉ

Johnson, Y., I. Boyce, and B. Waugh. 2002. Estimation of the abundance of chinook salmon (*Oncorhynchus tshawytscha*) in the upper Yukon River Basin using mark-recapture methods: 1990-1995. Can. Tech. Rep. Fish. Aquat. Sci. 2378: 98 p.

De 1990 à 1995, Pêches et Océans Canada (MPO) a mené des études de marquage et recapture du saumon quinnat adulte du fleuve Yukon. Jusqu'à 2,174 migrateurs amontants capturés dans deux filets rotatifs installés à la frontière internationale ont ainsi été munis d'étiquettes en spaghetti chaque année. Les saumons étiquetés ont été recapturés dans le cadre de la pêche commerciale prenant fin à 200 km en amont, qui a donné des prises de jusqu'à 12,028 individus. L'abondance allait de 41,187 à 56,679 saumons selon les estimations cumulées de Petersen et l'échappée, obtenue par soustraction des prises de ces chiffres, de 20,743 à 37,699 géniteurs. Les taux moyens de capture réalisés dans le cadre de la pêche commerciale, autochtone, domestique et récréative s'élevaient à 23,8 %, 15,8 %, 0,6 % et 1,3 %, respectivement. La vitesse de migration augmentait en fonction de la distance du lieu d'étiquetage. Certaines populations de géniteurs ont été dénombrées, mais une relation significative avec les données de marquage et recapture n'était pas apparente ($p > 0,05$). Une comparaison des prises commerciales de 1995 aux prises aux filets rotatifs réalisées par le MPO a révélé que les premières se composaient d'individus plus gros et plus âgés, tandis qu'une comparaison entre, d'une part, l'estimateur de Schaefer, l'estimateur de Darroch et l'estimateur stratifié de Petersen et, d'autre part, l'estimateur cumulé de Petersen a révélé qu'ils divergeaient de moins de 15 %.

INTRODUCTION

TAGGING PROJECT BACKGROUND

Fisheries and Oceans Canada[1] has used mark-recapture methods to derive chinook salmon (*Oncorhynchus tshawytscha*) abundance estimates in the upper Yukon River from 1982 to the present (excluding 1984). Abundance estimates are made using statistics from chinook salmon tagged at DFO fishwheels just upstream from the Canada - U.S. border and recaptured in a commercial fishery further upriver. The results of the Yukon River mark-recapture program are used by fishery managers in Canada and the U.S. to develop specific chinook salmon management plans in accordance with Canada - U.S. bilateral agreements and domestic management objectives. These management plans include the development of escapement goals upon which fishery regulations and catch limits are subsequently based. Fishery managers calculate in-season abundance estimates in order ensure escapement goals are met. The results of the Yukon River mark-recapture program are also used in treaty negotiations regarding joint management and sharing of transboundary chinook stocks that are ongoing between the U.S. and Canada.

This report presents results from the DFO Yukon River chinook mark-recapture program for the years 1990 to 1995. Results from a 1982-1983 radio-tagging and spaghetti tagging program are presented in Milligan et al. (1985). Results from the spaghetti tagging program conducted from 1985 to 1989 have not been published. Mark-recapture studies were also conducted by DFO in 1973 (Sweitzer 1974), 1974 (Brock 1976) and 1978 (DFO unpublished). Some results from the mark-recapture program have been published annually since 1985 in the Yukon River Salmon Season Review and Technical Committee Report prepared by the United States/ Canada Yukon River Joint Technical Committee (JTC). The JTC was established upon signing of the Pacific Salmon Treaty in 1985. The JTC is tasked with technical aspects of Yukon River salmon stock management and research. Annual reports by the Alaska Department of Fish and Game (ADF&G) also incorporate results from the mark-recapture program. A review of existing data was conducted in the preparation of this report, therefore data presented here supersede those previously reported. A bibliography of reports on stock-assessment studies conducted in the Canadian Yukon River is in Appendix 1.

YUKON RIVER BACKGROUND

The Yukon River headwaters lie within 30 km of the Pacific Ocean in the British Columbia north coastal mountains (Fig. 1). The river flows north and west in Canada, draining much of the Yukon Territory and then crosses the international boundary to continue through Alaska to the Bering sea. The length of the Yukon River is approximately 3,018 km – its drainage basin encompasses 844 800 km^2, approximately 342 875 km^2 (40.6%) of which are in Canada. The Yukon River basin is the fifth largest drainage in North America both in terms of land area and mean discharge (Milligan et al. 1985). It is comprised of six major sub-basins, namely the Pelly, Stewart,

[1] Formerly referred to as the Department of Fisheries and Oceans (DFO)

Teslin, White, Yukon mainstem and Porcupine River sub-basins (Milligan et al. 1985). Major headwater lakes include Kluane, Bennett, Marsh, Tagish, Atlin, Laberge, Teslin and Mayo lakes.

The two most abundant species of salmon found in the Canadian portion of the Yukon River are chinook salmon and chum salmon (*Oncorhynchus keta*) (Otto 1996). Coho salmon (*Oncorhynchus kisutch*) have occasionally been captured in the Canadian portion of the Yukon River by commercial fishers, and are regularly harvested in relatively low numbers in the Porcupine River (Otto 1996). The Yukon River also supports a number of other migratory and non-migratory fish species, some of which are mentioned in the section Other Species on page 47.

YUKON RIVER CHINOOK SALMON BACKGROUND

Upper Yukon River chinook salmon rear in freshwater for a period of one to two years after which they spend from two to six years in the ocean. Adult chinook salmon return to spawn in freshwater at the age of three to eight years. Returning adults enter the mouth of the Yukon River in late May and early June and reach the Dawson area in late June and early July. The chinook salmon migration to Yukon River headwater tributaries is the longest known salmon migration in North America (Milligan et al. 1985).

Spawning is known to occur in 96 Canadian streams (pers. comm. von Finster 2001). Canadian spawning habitat includes small and large tributaries, the mainstem Yukon River and lake outlets (Milligan et al. 1985). Some major Canadian spawning areas are the Big Salmon, Little Salmon, Nisutlin, Teslin and Ross Rivers and Yukon River mainstem channels.

FISHERY (RESOURCE USE) BACKGROUND

In Canada, Yukon River chinook salmon are caught in commercial, aboriginal, recreational and domestic fisheries. All of these fisheries are managed by DFO, and fishers must be licensed. The management priorities of DFO are, in order: 1) conservation (maintaining adequate escapement of stocks), 2) aboriginal food fish requirements and 3) all other fisheries.

A commercial fishery has operated near Dawson City since 1903 (Milligan et al. 1985). In 1982 the commercial fish plant Han Fisheries Ltd. opened in Dawson City (Otto 1996) and commercial fishing effort began to increase. In most recent years commercial fishery harvests have exceeded harvests from all other fisheries combined in the upper Yukon River basin. Commercial fishery catches from 1980 to 1995 are presented in Appendix 2.

The commercial fishery is controlled through the opening and closure of weekly fishing periods. Fishery managers adjust the commercial fishery openings and catch limits in-season to achieve pre-determined escapement goals. The Yukon River commercial fishery is discussed in greater detail in the section Capture Techniques and Fishery Regulations on page 5.

Total aboriginal catches of chinook salmon in the upper Yukon River from 1980 - 1996, as well as catches in the Porcupine River are provided in Appendix II. The aboriginal fishery is subject to few restrictions unless conservation issures arise (Otto 1996). Basic Needs Levels are currently being ascertained (Otto 1996). More information about the aboriginal fishery can be found in the annual aboriginal harvest study reports published by DFO (pre-1996 e.g. Wilson 1995), and LGL (post-1996 e.g. Blakely et al 2001).

Domestic licences permit non-aboriginal fishers to net salmon for personal use (Otto 1996). Domestic licences are held by a few individuals who harvested less than 300 chinook in total and no chum each year between 1990 - 1995. Mahoney (1997) describes the domestic salmon fishery in the Yukon.

Recreational angling for chinook salmon by residents and non-residents also takes place at various locations in the Yukon River system. The recreational fishery lacks a reliable reporting system. From 1990 - 1994 it was estimated that 300 chinook salmon were caught by anglers annually. For 1995 this estimate was increased to 700 chinook salmon. Otto (1996) examined the Yukon recreational salmon fishery in detail.

OBJECTIVES

The objectives of the 1990 - 1995 upper Yukon River chinook salmon mark-recapture program were to determine:

1. in-season abundance estimates for use by fishery managers in monitoring catch and escapement objectives;
2. final estimates of border passage abundance;
3. estimates of Canadian drainage spawning escapements;
4. harvest rates in Canadian fisheries;
5. migration timing and migration rates;
6. sex, length and age composition profiles of chinook salmon captured for mark application and recaptured in the commercial fishery.

METHODS

MARKING EVENT

Capture Techniques

Two fishwheels were used to live capture chinook salmon for the Yukon River mark-recapture program. The fishwheels were located on the Canadian side of the Yukon - Alaska border approximately 140 river kilometres downstream of Dawson City, Yukon (Figure 1). The White Rock fishwheel was located 10 kilometres from the international border on the right bank facing

downstream. The Sheep Rock fishwheel was located 17 kilometres from the border, also on the right bank. These sites were the same sites used in the 1982, 1983 and 1985-1989 DFO chinook tagging studies. A third fishwheel, known as the Moose Rock fishwheel, was located 13 kilometres upstream of the border. It was used in the DFO tagging program from 1982 until 1989.

The White Rock and Sheep Rock fishwheel sites were downstream of all Canadian commercial fishing activity. The fishwheels were positioned at the upstream limits of eddies where mainstem currents were sufficient to turn them. The two-basket fishwheels fished to a 3m depth by 3m width. Speed of rotation was approximately three to four rotations per minute subject to water velocity and could be adjusted by the addition or removal of plywood sections of the paddles. Changes in water levels required that fishwheel position be adjusted relative to the shore in order to achieve maximum efficiency and prevent the baskets from hitting bottom. By raising or lowering an axle, approximately 1m of depth adjustment was possible without major changes to the position or structure of the fishwheel. The wheels were secured by 0.95 cm steel cables attached to adjacent rock outcrops and several large polypropylene ropes. They were kept out from shore by logs cut on site. Holding pens were constructed with a metal grill on the bottom and plywood sides with holes in upstream and downstream ends to allow a continuous flow of fresh river water to the captured fish. The fishwheels were of the same design as those used in the 1982-83 study (Milligan et al. 1985) with minor modifications for strength and increased reliability. Over winter the fishwheels were stored onshore close to the fishing sites.

Fishwheels were operated in order to sample the entire run. Fishwheel operational periods are shown in Table 1. In all years 1990 - 1991 and 1993 - 1995 the fishwheels began fishing between June 11 and June 22. Due to high water conditions in 1992, the White Rock and Sheep Rock fishwheels were not operational until July 2 and August 8 respectively. In all years 1990 - 1995 the fishwheels continued to operate after the completion of the chinook run (until the end of September or mid-October). This permitted live-capture and application of spaghetti tags to migrating adult Yukon River chum salmon for a similar DFO chum mark-recapture program. Effort was constant during the chinook run periods from 1990 – 1995, except in 1992, when the Sheep Rock fishwheel was not spinning until after the run had commenced. With the exception of short periods for maintenance or repair, fishwheels were operational 24 hours daily.

Table 1. Sheep Rock and White Rock fishwheel operation start dates, 1990 - 1995.

	Start date	
Year	Sheep Rock	White Rock
1990	16 June	18 June
1991	16 June	19 June
1992	08 August	02 July
1993	13 June	11 June
1994	19 June	17 June
1995	18 June	22 June

Mark Application and Sex, Length and Age Sampling

Chinook salmon captured in the fishwheels were transferred by dipnet to a tagging box located in the attending boat. The tagging box consisted of an inclined tagging tray containing fresh water in which the salmon's head and gills remained immersed throughout the tagging procedure. Water in the tagging tray was changed frequently during tagging.

Spaghetti tags were consecutively numbered, international orange in colour, hollow plastic PVC tubing (size 13 - approximately 2 mm in diameter). Each tag had DFO identification and measured approximately 30 cm in length after it was clipped from the roll. These tags were obtained in 300 m rolls from Floy Tag Manufacturing Incorporated, Seattle, Washington.[2] Spaghetti tags were applied through the musculature approximately 1.3 cm beneath the dorsal surface under the dorsal fin using a 15 cm long needle-like applicator. After insertion through the back of the fish, the spaghetti tag was knotted tightly together with a single overhand hitch. From 1990 to 1993 all healthy chinook salmon captured in the fishwheels were tagged. Due to concern that small size fish were biasing the abundance estimate because they were more likely to be captured in the fishwheels than in the commercial fishery, in 1994 and 1995 only healthy chinook salmon greater than 450 mm in fork length were tagged.

Each fish was sampled for sex, length and age while in the tagging box. Sex was determined by visual examination of external morphological characteristics or expelled milt or eggs. Fork length was determined to the nearest centimetre with a metre stick attached to the tagging box. For subsequent laboratory age analysis, three scales were removed from the preferred area located two rows above the lateral line along an imaginary line extending from the anterior edge of the anal fin to the posterior dorsal. Tagging and sampling generally took less than thirty seconds. Tagging and sampling were conducted twice daily (morning and evening).

Ages were determined using standard techniques and recorded according to the Gilbert Rich classification system.[3] All scale pressing and reading was done at the DFO scale lab in Vancouver, BC.

RECAPTURE EVENT

Capture Techniques and Fishery Regulations

Recapture data used in developing population estimates were obtained from tags provided by commercial fishers operating downstream of the Stewart River. A payment of two dollars was made for each tag returned with information on the type of fishery, date and location of capture. Commercial fishers were legally required by DFO to report their daily catches and turn in tags. Commercial fishers were provided with a form upon which to record various catch statistics. Fishers could give catch statistics and tags to the DFO fishery officer stationed in Dawson City.

Commercial fishing was legally permitted on the Yukon River from approximately one kilometre downstream of Tatchun Creek to just downstream of Dozen Islands, with the exception of a stretch of approximately one kilometre above and one kilometre below Dawson City (Figure 1). The fishing effort was greatest approximately 5 and 215 river kilometres upstream of the Sheep Rock

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[2] Mention of trade names does not constitute endorsement by DFO.

[3] The first number in a Gilbert Rich age code indicates the age the fish will be at spawning. The second number indicates the year of life in which the fish migrated to the ocean. For example, an age 5^{3} fish will reach five years of age (from the time it was deposited as an egg) at spawning . It migrated to the sea in the spring of its third year of life (from the time it was deposited as an egg). Therefore it spent two summers in freshwater. An age 5^{1} fish spent zero complete summers in freshwater (assuming spring or summer migration).

fishwheel, between Dozen Islands and the Sixty Mile River respectively. Commercial fishers had to be licensed with DFO and could only fish during official fishery openings. Public notices were posted to indicate when the fishery was open. From 1990 - 1995 the commercial fishery generally opened for 24 hours on the Monday following capture of the first chinook salmon at the DFO fishwheels (Table 2). If there was insufficient time to notify fishers of the first opening, the opening was postponed to the next Monday and extended to 48 hours. Commercial fishery openings were determined by fishery managers according to a combination of long term and in-season management goals and objectives. Adherence to regulations in the commercial fishery was enforced by fishery officers or patrollmen. Although the commercial chinook fishery had an official end date, a few chinook salmon were caught after this time because some commercial fishers began fishing for chum salmon.

In the years 1990 - 1995 a maximum of 19 fishers per day (1994) fished commercially for chinook salmon (Table 2). Fishers used nets and occasionally fishwheels set in locations that varied little from year to year. Each fisher could use up to four gillnets with a maximum combined length of 90 metres or a maximum of three fishwheels or a specified combination of gillnets and fishwheels. Gillnet mesh size was not regulated and most commercial fishers used a mesh size of 18 to 21 centimetres for chinook salmon (Smith pers. comm. 1997). Not all licensed fishers fished continuously throughout the opening. The fishery was economy-driven and most fishers adjusted their effort in response to chinook salmon market prices (Coukell pers. comm. 1997).

Table 2. Number of days fished, catch and effort statistics in the chinook salmon commercial fishery below the Stewart River, 1990 - 1995. Catch/ boat-day is calculated by dividing the catch in a given statistical week by the product of the corresponding number (i.e. of boats) fishing and days fished.

Statistical Week	Days fished		1990				1991				1992	
27	Closed	0	0	0	Closed	0	0	0	closed	0	0	0
28	1	5	15	3.00	1	6	20	3.33	closed	0	0	0
29	1	11	90	8.18	1	8	252	31.50	closed	0	0	0
30	4	17	4408	64.82	3	16	2189	45.60	closed	0	0	0
31	4	18	3938	54.69	4	14	2354	42.04	2	13	1116	42.92
32	4	16	1516	23.69	5	16	3316	41.45	4	17	4293	63.13
33	4	6	381	15.88	4	14	1894	33.82	4	15	3751	62.52
34	4	2	88	11.00	2	9	355	19.72	3	8	1093	45.54
35	3	3	5	0.56	2	1	9	4.50	1	0	0	0.00
36	3	13	11	0.28	2	3	7	1.17	1	3	15	5.00
37	4	14	4	0.07	4	10	15	0.38	3	12	30	0.83
38	4	14	1	0.02	4	13	4	0.08	3	12	4	0.11
39	4	15	2	0.03	4	15	1	0.02	2	10	4	0.20
40	3	12	0	0.00	2	15	0	0.00	2	11	0	0.00
41	2	3	0	0.00	Closed	0	0	0	2	3	0	0.00
Total catch:			10459[4]				10416				10306	

	1993				1994				1995			
Statistical Week	Days fished	Number fishing	Catch	Catch/ boat-day	Days fished	Number fishing	Catch	Catch/ boat-day	Days fished	Number fishing	Catch	Catch/ boat-day
27	1	7	34	4.86	closed	0	0	0	2	9	326	18.11
28	1	10	170	17.00	2	13	141	5.42	3	16.33	2236	45.63
29	3	15	1781	39.58	3	19	1772	31.09	3	17	2324	45.57
30	4	17	3154	46.38	5	15	3821	50.95	3	14	2908	69.24
31	4	17	2971	43.69	5	13.6	2782	40.91	3	14.33	2085	48.49
32	4	17	1444	21.24	5	13	2225	34.23	3	10.67	987	30.84
33	3	11	407	12.33	4	7.75	797	25.71	3	4.67	173	12.36
34	2	1	15	7.50	3	2.5	118	15.73	2	0	0	0.00
35	1	3	4	1.33	closed	0	0	0	2	7.5	3	0.20
36	2	10	6	0.30	closed	0	0	0	3	12.33	2	0.05
37	2	13	2	0.08	3	15	3	0.07	3	11.33	0	0.00
38	1	11	0	0.00	3	16	3	0.06	3	15	0	0.00
39	Closed	0	0	0	3	13	2	0.05	3	17.67	0	0.00
40	Closed	0	0	0	3	13	2	0.05	closed	0	0	0
41	Closed	0	0	0	3	10	0	0.00	closed	0	0	0
Total catch:			9988				11666				11044	

[4] Total adjusted post-season to 10,448; adjustment by statistical week is not available.

Sex, Length and Age Sampling

The commercial fishery catch of chinook salmon was sampled by DFO contract personnel in 1994 and 1995. The 1994 chinook salmon sample was limited in scope – the intent was only to obtain both scale and pectoral fin samples in order to compare ages derived from the two structures. The 1994 sample consisted of 150 chinook salmon obtained from the Han fish plant and is not presented in this report. The 1995 chinook salmon sample was intended to characterise the commercial harvest. In 1995, a total of 1,353 samples was obtained. A small number of samples were obtained at the Han fish plant, however the majority came directly from various fish camps. It is not believed that fish delivered to the Han plant were representative of the commercial harvest as a whole. Sampling methodology was similar to that associated with fishwheel catch sampling, described in the section Mark Application and Sex, Length and Age Sampling on page 4. However, a flexible tape was used to measure length on larger fish and, in addition to fork length, post-orbital hypural (POH) length was taken. POH length is measured from the posterior of the eye to the hypural plate at the tail and is the best measurement for sexually mature salmon since it is not influenced by tail degeneration or kype (snout) development (Shaw 1994). This length measurement was not taken at the time of tagging due to the chance of causing eye injury and the difficulty of locating the hypural plate on moving fish. Fork lengths were used for all length comparisons in fishwheel and commercial fishery samples. It is believed that fork lengths are comparable between the sampling areas (the tagging sites and the commercial fishing zone) – the length of a given fish is unlikely to change significantly from the time of tagging to the time of harvest.

The sex and length composition of the 1995 commercial fishery catch was estimated using the 1995 sample data. To do this, the sex and length composition of the commercial biological sample by statistical week was applied to the corresponding weekly commercial catch total (Table 2) and the weekly results were summed to obtain figures for the entire catch.

ABORIGINAL, DOMESTIC AND RECREATIONAL FISHERIES: TAG RECOVERY AND COLLECTION OF HARVEST STATISTICS

Aboriginal, domestic and recreational fishers were also eligible for a payment of two dollars in exchange for each tag returned with information on the type of fishery, date and location of capture. Most of these fishers had knowledge of the tagging program. Information on the mark-recapture program has been provided to the public through various media since the inception of the program in 1982.

In 1990 and 1991, tag recoveries and harvest information was solicited from aboriginal fishers during post-season interviews and postal surveys. In 1992 and 1993, a combination of in-season and post-season methods was used. In 1994 and 1995, all aboriginal fishery chinook salmon tag recoveries and harvest information was solicited in-season. Methodology and thoroughness varied somewhat between communities for the in-season surveys. Some fishers filled in daily catch calendars, some were visited daily by a food fish officer and others were not contacted at all or did not provide any information about their harvests. More information can be found in the Aboriginal harvest studies published annually by DFO (e.g. Wilson 1995).

Some tags were sent in by mail from aboriginal, domestic and recreational fishers. Some tagged fish ascended the Whitehorse Rapids Fishway, where staff recorded the tag number, sex and condition of these fish and the date. A small number of tags was returned by Alaskans downstream of the tagging site. Some tags were recovered on spawning grounds by members of the public or by DFO staff conducting spawning ground surveys.

Harvest statistics for the domestic and recreational chinook salmon fisheries were estimated by DFO for all years 1990 - 1995.

ESCAPEMENT INDEX SURVEYS

Chinook salmon escapement counts were conducted at several index areas for the period 1990 - 1995. One of these indices is the Whitehorse Rapids Fishway, where chinook salmon bypassing the Whitehorse dam have been enumerated since 1959. Aerial surveys were conducted each year on the following rivers: Little Salmon River, Big Salmon River, Nisutlin River, Ross River, Wolf River and Tincup Creek (Figure 1). Except for 1990, when aerial surveys were conducted by the Alaska Department of Fish and Game (ADF&G) using a Super Cub fixed wing aircraft, one or two observers conducted the aerial counts from a Bell 206B helicopter. Tatchun River, locally known as Tatchun Creek, was surveyed on foot by one or more individuals at least once each year from 1990 - 1995 (Figure 1). Some surveys were conducted over the entire length of a river, while others covered specific sections only. Generally, one survey was conducted for each index area annually and attempt was made to time each survey close to the time of peak spawning. The section of the form in which the estimated total fish in the stream can be entered was not used. Only actual counts were recorded. The survey counts do not represent actual escapement, since runs are generally protracted, with early spawners disappearing before late ones arrive. Although the spawning ground surveys and Whitehorse Rapids Fishway counts were not used in developing drainage-wide abundance estimates, they are included in this report as potential indicators of abundance with which the mark-recapture results may be compared.

STATISTICAL METHODS

There were two sets of chinook salmon data analysed: 1) tag release and recapture data and 2) biological data obtained from sampling. All computation and statistical analysis were done using Lotus or Microsoft Excel Version 5.0c.[5] Darroch abundance estimates were calculated using the SPAS (Stratified Population Analysis System) program (Arnason et al. 1996).

In this report much of the data is presented according to statistical week. Statistical weeks began at 00:00 hours on a Sunday and ended at 24:00 hours on a Saturday. Statistical week ending dates from 1990 to 1995 are presented in Appendix 3.

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[5] Ibid.

Adjustments for Capture Selectivity

In order to assess the appropriateness of various methods of estimating population abundance, chi-square tests were used to detect possible differences between the probability of capture and recapture for different sexes and length classes in the Yukon River chinook mark-recapture program. The sex ratio and length composition in the tagged chinook salmon released at the fishwheel were compared to the sex ratio and length composition in the commercial catch of tagged fish. To test for capture selectivity by length the marked and recaptured chinook salmon samples were distributed into four fork length classes: < 800 mm, 800 - 899 mm, 900 - 999 mm and > 999 mm. Age classes were not included in chi-square analysis as it is believed that length more than age influences catchability (Bromaghin 1990). Chinook salmon of unknown sex or length were excluded from this test.

Abundance Estimates

A pooled Petersen abundance estimate was calculated for each year 1990 - 1995. The results of testing for capture selectivity suggested that the 1990, 1992, 1993 and 1995 abundance estimates should be calculated separately for each sex and that the abundance estimates for all years 1990 - 1995 should be calculated separately for each length class (the section Adjustment for Capture Selectivity on page 35, Table 29 and Table 30). This analysis would require that the entire commercial catch associated with tag recoveries be separated into the relevant classes. However, a representative commercial biological sample is necessary to estimate the sex and length class ratios in the commercial catch. As previously indicated only the 1995 commercial catch was biologically sampled in a representative manner. Therefore abundance estimates by sex and length as well as for sex and length classes combined, were calculated only for the 1995 chinook salmon run. The estimators used for 1995 data were 1) pooled Petersen (Seber 1982), 2) Schaefer estimate for stratified populations (according to Ricker 1975) and 3) Darroch (Darroch 1961).

The small numbers of downstream recoveries of tagged chinook salmon (see Table 20) were not subtracted from the marked sample total used in the calculation of 1990 - 1995 population estimates. Tags from downstream recoveries were returned to DFO after the end of the season. The loss of these fish from the population vulnerable to recapture is likely accounted for in the 10% reduction of the total number of tags applied, for use in abundance estimate calculation. This reduction is explained in the following section.

Pooled Petersen Abundance Estimates, 1990 – 1995: Recapture data from the 1990 - 1995 chinook salmon mark-recapture program were available as weekly totals. This data was pooled to calculate a Petersen abundance estimate for each year 1990 - 1995. Separate estimates for male and female chinook salmon and for the length classes of chinook salmon indicated in Section 2.5.1 were also calculated and summed to provide two other Petersen abundance estimates for the 1995 run.

The Petersen formula adjusted for sample bias is:

$$N_{Petersen} = \frac{(M+1)\cdot(C+1)}{(R+1)}$$

where:

$N_{Petersen}$ = abundance;
M = total number of fish marked;
C = catch examined for tags and;
R = number of recaptured tags in the sample.

Upper and lower 95% confidence limits were determined for the Petersen abundance estimates. This was done by calculating the 95% confidence limits for R to give a new value r. Then the upper and lower limits of the pooled Petersen estimate were determined using r instead of R.

Since all values of R were greater than 50, Pearson's formula (Ricker 1975) was used to calculate r:

$$r = 95\%\ confidence\ limits\ of\ R = X + 1.92 \pm 1.96 \cdot \sqrt{X + 1.0}$$

where:

$X = R$.

Confidence limits could not be determined for estimates which had been summed.

To adjust for tag loss, downstream migration loss and mortality the total number of tags applied was reduced by 10% for use in the Petersen estimate. This figure of 10% was estimated from the results of a Yukon River chinook salmon radio-tagging study conducted by Milligan et al. (1985). In this study, 24% of radio-tagged chinook were classified as mortalities or regurgitations. Mortalities could have been the result of injuries from gillnet encounters, tag-induced injuries, migratory delay associated with tagging and other factors. It was assumed that the loss of radio-tagged individuals from the marked population as a direct result of tagging would be greater than the loss of spaghetti tagged individuals, because spaghetti tag application is probably less stressful.

Schaefer Estimate For Stratified Populations, 1995: Three Schaefer abundance estimates were calculated for 1995. One estimate used the entire chinook salmon mark-recapture sample, with sexes and lengths combined. The second estimate was the sum of two separate abundance estimates for male and female chinook salmon. The third estimate was the sum of four separate abundance estimates for the length classes indicated in the section Length Composition on page 32.

Time of tagging and release was divided into s time periods designated as i and time of recapture was divided into t time periods designated as j. Data were arranged in matrices according to time intervals of statistical weeks. Statistical weeks at the beginning and at the end of the run were selectively pooled into single strata in order to reduce the number of cells containing low or zero values (Arnason et al. 1996). The only requirement for this selective pooling is that strata are mutually exclusive such that an individual can be marked in only one initial stratum and can be recovered in only one final stratum (Arnason et al. 1996). The original data matrices used are in Table 3 to Table 9.

For each cell in the table, an estimate (N_{ij}) was made of the proportion of the population available for marking in period *i and* for recapture in period *j*:

$$N_{ij} = R_{ij} \cdot \left(\frac{M_i}{R_i}\right) \cdot \left(\frac{C_j}{R_j}\right)$$

where:

N_{ij} = population available for marking in period *i* and available for recapture in period *j*;
M_i = number of fish marked in period *i*;
C_j = number of fish caught and examined in period *j*;
R_i = total recaptures of fish tagged in period *i*;
R_j = total recaptures in period *j*.

The estimated total population was the sum of all strata. The total number of tags applied (M_i) was reduced by 10% as described for the pooled Petersen estimate. No confidence intervals were calculated. The SPAS program (Arnason et al. 1996) easily calculates confidence intervals, however even in SPAS these can not be determined for estimates which are the result of summations.

For separate sex and length class estimates, the sex and length compositions of the marked samples (M_i) and the recapture samples (R) were known from the fishwheel tagging records. The sex and length composition of the commercial catch associated with the recovered tags (C_j) was derived using the commercial biological sample obtained in 1995 (see the sections: Sex, Length and Age Sampling on page 8; Sex Composition, Fishwheel and Commercial Samples on page 26; Length Composition on page 32).

Table 3. Original tag data matrix used to calculate 1995 Schaefer abundance estimate for combined sexes and length classes of chinook salmon.

	Recapture week								
Statistical week applied	27-28	29	30	31	32	33-36	Tags recovered (#)	Tags applied (#)	Tags applied/ tags recovered
26 - 27	8	1	0	0	0	0	9	87	9.67
28	17	36	0	1	0	0	54	263	4.87
29	0	54	28	1	0	0	83	387	4.66
30	0	0	50	70	8	0	128	633	4.95
31	0	0	0	55	35	0	90	395	4.39
32	0	0	0	0	23	5	28	121	4.32
33 - 36	0	0	0	0	0	2	2	51	25.50
Total	25	91	78	127	66	7	394	1937	
Commercial catch	2562	2324	2908	2085	987	178			
Catch/ tags recovered	102.48	25.54	37.28	16.42	14.95	25.43			

Table 4. Original tag data matrix used to calculate Schaefer abundance estimate for male chinook salmon.

	Recapture week								
Statistical week applied	27-28	29	30	31	32	33-36	Tags recovered (#)	Tags applied (#)	Tags applied/ tags recovered
26 - 27	3	0	0	0	0	0	3	51	17.10
28	8	22	0	1	0	0	31	176	5.69
29	0	26	13	1	0	0	40	272	6.80
30	0	0	33	38	3	0	74	427	5.76
31	0	0	0	31	20	0	51	295	5.79
32	0	0	0	0	9	3	12	77	6.45
33 - 36	0	0	0	0	0	1	1	28	27.90
Total	11	48	46	71	32	4	212	1326	
Male commercial catch	1824	1327	1457	911	416	83			
Catch/ tags recovered	165.82	27.65	31.67	12.83	13.00	20.75			

Table 5. Original tag data matrix used to calculate Schaefer abundance estimate for female chinook salmon.

	Recapture week								
Statistical week applied	27-28	29	30	31	32	33-36	Tags recovered (#)	Tags applied (#)	Tags applied/ tags recovered
26 - 27	5	1	0	0	0	0	6	36	6.00
28	9	14	0	0	0	0	23	87	3.80
29	0	28	15	0	0	0	43	115	2.68
30	0	0	17	32	5	0	54	206	3.82
31	0	0	0	24	15	0	39	100	2.56
32	0	0	0	0	14	2	16	44	2.76
33 - 36	0	0	0	0	0	1	1	23	23.40
Total	14	43	32	56	34	3	182	611	
Female commercial catch	738	997	1451	1174	571	95			
Catch/ tags recovered	52.71	23.19	45.34	20.96	16.79	31.67			

Table 6. Original tag data matrix used to calculate Schaefer abundance estimate for chinook salmon < 800 mm in fork length.

	Recapture week								
Statistical week applied	27-28	29	30	31	32	33-36	Tags recovered (#)	Tags applied (#)	Tags applied/ tags recovered
26 - 27	3	0	0	0	0	0	3	42	14.10
28	3	11	0	1	0	0	15	132	8.82
29	0	15	6	1	0	0	22	195	8.88
30	0	0	14	23	1	0	38	325	8.55
31	0	0	0	22	14	0	36	253	7.03
32 - 36	0	0	0	0	7	2	9	95	10.50
Total	6	26	20	47	22	2	123	1042	
Commercial catch	792	400	345	436	78	15			
Catch/ tags recovered	132.00	15.38	17.25	9.28	3.55	7.50			

Table 7. Original tag data matrix used to calculate Schaefer abundance estimate for chinook salmon 800 - 899 mm in fork length.

	Recapture week								
Statistical week applied	27-28	29	30	31	32	33-36	Tags recovered (#)	Tags applied (#)	Tags applied/ tags recovered
26-27	2	1	0	0	0	0	3	31	10.20
28	6	14	0	0	0	0	20	79	3.96
29	0	17	15	0	0	0	32	118	3.68
30	0	0	16	24	3	0	43	181	4.21
31	0	0	0	15	8	0	23	72	3.13
32-36	0	0	0	0	6	2	8	31	3.83
Total	8	32	31	39	17	2	129	512	
Commercial catch	607	548	648	369	165	11			
Catch/ tags recovered	75.88	17.13	20.90	9.46	9.71	5.50			

Table 8. Original tag data matrix used to calculate Schaefer abundance estimate for chinook salmon 900 - 999 mm in fork length.

	Recapture week								
Statistical week applied	27-28	29	30	31	32	33-36	Tags recovered (#)	Tags applied (#)	Tags applied/ tags recovered
26-27	3	0	0	0	0	0	3	11	3.60
28	4	6	0	0	0	0	10	34	3.42
29	0	16	6	0	0	0	22	62	2.82
30	0	0	12	12	2	0	26	88	3.39
31	0	0	0	15	10	0	25	50	2.02
32	0	0	0	0	10	1	11	27	2.45
33-36	0	0	0	0	0	2	2	14	7.20
Total	7	22	18	27	22	3	99	286	
Commercial catch	756	995	1195	763	408	73			
Catch/ tags recovered	108.00	45.23	66.39	28.26	18.55	24.33			

Table 9. Original tag data matrix used to calculate Schaefer abundance estimate for chinook salmon > 999 mm in fork length. Table shows tag applications and recoveries by statistical week for chinook salmon > 999 mm in fork length captured in Yukon River Sheep Rock and White Rock fishwheels, 1995.

	Recapture week							
Statistical week applied	27-28	29	30	31	32-36	Tags recovered (#)	Tags applied (#)	Tags applied/ tags recovered
26-28	4	5	0	0	0	9	21	2.30
29	0	6	1	0	0	7	12	1.67
30	0	0	8	9	2	19	39	2.04
31-36	0	0	0	3	3	6	26	4.35
Total	4	11	9	12	5	41	98	
Commercial catch	405	381	715	519	432			
Catch/ tags recovered	101.25	34.64	79.44	43.25	86.40			

Darroch Estimate for Stratified Populations, 1995: Chinook salmon abundance for 1995 was estimated using the Darroch method for stratified populations. As described for the Schaefer estimate, three Darroch abundance estimates were calculated. One estimate was for all sexes and length classes of chinook salmon combined, and the other two were separate estimates by sex and by length class. These Darroch estimates and 95% confidence intervals were generated in SPAS. Confidence intervals could not be determined for individual strata nor for estimates which were the result of summations.

Data were arranged in matrices according to the protocol described for the Schaefer estimate. Statistical weeks at the beginning and at the end of the run were collapsed into single strata in order to reduce the number of cells with low or zero values. The original data matrices used are in Table 10 to Table 16.

For each recapture stratum j in the matrix, an estimate (N_j) was made of the number of unmarked fish at the time of tagging that ended up in that jth stratum (Darroch 1961):

$$N_j = D_n \cdot S^{-1} \cdot t$$

where:

D_n = a diagonal matrix of the number of untagged fish observed in each recapture stratum j;
S = the number of tag recoveries in each recapture stratum j which were released in tagging stratum i;
t = a vector of the number of tagged fish released per tagging stratum.

The estimate of the total unmarked abundance is the sum of the N_j. The point in time for which the Darroch technique estimates abundance changes with the relationship between number of marking and recapture weeks and is discussed in Section 4.4. The total number of tags applied was reduced by 10% as described for the pooled Petersen estimate.

The data matrix used to calculate the 1995 Darroch estimate for combined sexes and length classes of chinook salmon consisted of pooled tagging weeks 26 - 28 and 32 - 36 and pooled recapture weeks 27 - 29 and 32 -36 with time periods of marking $s = 5$ and time periods of recapture $t = 4$ (Table 10). For the male chinook salmon Darroch estimate, collapsing statistical weeks resulted in pooled tagging weeks 26 - 28 and 33 - 36 and pooled recapture weeks 27 - 29 and 33 - 36 with $s = 6$ and $t = 5$ (Table 11). For the female chinook salmon Darroch estimate, tagging weeks 26 - 28 and 31 - 36 and recapture weeks 27 - 29 and 32 - 36 were pooled resulting in $s = 4$ and $t = 4$ (Table 12). For chinook salmon < 800 mm and 800 - 899 mm in fork length the data matrix contained pooled tagging weeks 26 - 27 and 32 - 36 and pooled recapture weeks 27 - 29 and 32 - 36 with $s = 6$ and $t = 4$ (Table 13 and 14). For chinook salmon 900 - 999 mm in fork length tagging weeks 26 - 27 and 33 - 36 and recapture weeks 27 - 29 and 32 - 36 were pooled with s = 7 and t = 4 (Table 15). The data matrix for chinook salmon > 999 mm in fork length contained pooled tagging weeks 26 - 29 and 31 - 36 and pooled recapture weeks 27 - 30 and 31 - 36 with $s = 3$ and $T=2$ (Table 16).

Table 10. Original tag data matrix used to calculate the 1995 Darroch abundance estimate for combined sexes and length classes of chinook salmon. Time periods of tagging and release s = 5 and time periods of recapture t = 4.

	Recapture week						
Statistical week applied	27-29	30	31	32-36	Tags recovered	Tags applied	Tags applied/ tags recovered
26 – 28	62	0	1	0	63	350	5.56
29	54	28	1	0	83	387	4.66
30	0	50	70	8	128	633	4.95
31	0	0	55	35	90	395	4.39
32 – 36	0	0	0	30	30	172	5.73
Total	116	78	127	73	394	1937	
Commercial catch	4886	2908	2085	1165			
Catch/ tags recovered	42.12	37.28	16.42	15.96			

Table 11. Original tag data matrix used to calculate Darroch abundance estimate for male chinook salmon. Time periods of tagging and release s = 6 and time periods of recapture t = 5.

	Recapture week							
Statistical week applied	27-29	30	31	32	33-36	Tags recovered (#)	Tags applied (#)	Tags applied/ tags recovered
26 - 28	33	0	1	0	0	34	227	6.68
29	26	13	1	0	0	40	272	6.80
30	0	33	38	3	0	74	427	5.77
31	0	0	31	20	0	51	295	5.78
32	0	0	0	9	3	12	77	6.42
33 - 36	0	0	0	0	1	1	28	28.00
Total	59	46	71	32	4	212	1326	
Male commercial catch	3151	1457	911	416	83			
Catch/ tags recovered	53.41	31.67	12.83	13.00	20.75			

Table 12. Original tag data matrix used to calculate Darroch abundance estimate for female chinook salmon. Time periods of tagging and release s = 4 and time periods of recapture t = 4.

	Recapture week						
Statistical week applied	27-29	30	31	32-36	Tags recovered (#)	Tags applied (#)	Tags applied/ tags recovered
26 - 28	29	0	0	0	29	123	4.24
29	28	15	0	0	43	115	2.67
30	0	17	32	5	54	206	3.81
31-36	0	0	24	32	56	167	2.98
Total	57	32	56	37	182	611	
Female commercial catch	1735	1451	1174	666			
Catch/ tags recovered	30.44	45.34	20.96	18.00			

Table 13. Original tag data matrix used to calculate Darroch abundance estimate for chinook salmon < 800 mm in fork length. Time periods of tagging and release s = 6 and time periods of recapture t = 4.

	Recapture week						
Statistical week applied	27-29	30	31	32	Tags recovered (#)	Tags applied (#)	Tags applied/ tags recovered
26 - 27	3	0	0	0	3	42	14.00
28	14	0	1	0	15	132	8.80
29	15	6	1	0	22	195	8.86
30	0	14	23	1	38	325	8.55
31	0	0	22	14	36	253	7.03
32 - 36	0	0	0	9	9	95	10.56
Total	32	20	47	24	123	1042	
Commercial catch	1192	345	436	93			
Catch/ tags recovered	37.25	17.25	9.28	3.88			

Table 14. Original tag data matrix used to calculate Darroch abundance estimate for chinook salmon 800 - 899 mm in fork length. Time periods of tagging and release s = 6 and time periods of recapture
t = 4.

	Recapture week						
Statistical week applied	27-29	30	31	32-36	Tags recovered (#)	Tags applied (#)	Tags applied/ tags recovered
26-27	3	0	0	0	3	31	10.33
28	20	0	0	0	20	79	3.95
29	17	15	0	0	32	118	3.69
30	0	16	24	3	43	181	4.21
31	0	0	15	8	23	72	3.13
32-36	0	0	0	8	8	31	3.88
Total	40	31	39	19	129	512	
Commercial catch	1155	648	369	176			
Catch/ tags recovered	28.88	20.90	15.38	16.00			

Table 15. Original tag data matrix used to calculate Darroch abundance estimate for chinook salmon 900 - 999 mm in fork length. Time periods of tagging and release s = 7 and time periods of recapture t = 4.

	Recapture week						
Statistical week applied	27-29	30	31	32-36	Tags recovered (#)	Tags applied (#)	Tags applied/ tags recovered
26-27	3	0	0	0	3	11	3.67
28	10	0	0	0	10	34	3.40
29	16	6	0	0	22	62	2.82
30	0	12	12	2	26	88	3.38
31	0	0	15	10	25	50	2.00
32	0	0	0	11	11	27	2.45
33-36	0	0	0	2	2	14	7.00
Total	29	18	27	25	99	286	
Commercial catch	1751	1195	763	481			
Catch/ tags recovered	60.38	66.39	28.26	19.24			

Table 16. Original tag data matrix used to calculate Darroch abundance estimate for chinook salmon > 999 mm in fork length. Time periods of tagging and release s = 3 and time periods of recapture t = 2.

	Recapture week				
Statistical week applied	27-30	31-36	Tags recovered (#)	Tags applied (#)	Tags applied/ tags recovered
26-29	16	0	16	33	2.06
30	8	11	19	39	2.05
31-36	0	6	6	26	4.33
Total	24	17	41	98	
Commercial catch	1501	951			
Catch/ tags recovered	62.54	55.94			

Spawning Escapement and Survey Counts

Spawning escapement was determined by subtracting the total recorded catch in all fisheries from the final pooled Petersen abundance estimates.

Linear regression was used to assess the relationship between spawning escapement estimates based on the Petersen estimate and the yearly means of the spawning area index counts (see the section Escapement Index Surveys on page 45), over the period from 1990 to 1995. Means were used instead of totals since some indices were not surveyed every year and some counts had to be excluded due to sub-optimal viewing conditions.

Harvest Rate

The harvest rate of each fishery was determined with the following formula:

harvest rate = (catch)/(border escapement).

where:

border escapement = pooled Petersen abundance estimate.

Migration Rates

To calculate migration rates, data from tagged fish were separated into three categories based on location of recapture. Locations of recapture in the commercial fishery were between the Canada - U.S. border and the Forty Mile River and between the Forty Mile River and the Stewart River. The third category comprised chinook salmon that had been observed at the Whitehorse Rapids Fishway. Separate migration rates were calculated for each category of chinook salmon recaptures. Migration rates were calculated for each year 1990 - 1995 and a mean and standard deviation over this six year period at each recapture location was determined. The following formula was used:

migration rate = (distance travelled)/(elapsed time).

The rates for all chinook salmon in each recapture location were averaged to give a mean daily migration rate.

RESULTS

MARK-RECAPTURE EXPERIMENT

Fishwheel Catches and Tagging

The number and sex ratio of chinook salmon captured by the fishwheels from 1990 - 1995 is presented in Table 17. Total fishwheel catches ranged from a low of 1,241 in 1993 to a high of 2,215 in 1995.

Table 17. Summary and sex ratios for Yukon River chinook salmon captured in DFO fishwheels, captured in the commercial fishery and through the Whitehorse Rapids Fishway from 1990 - 1995. Dawson area commercial catches include all chinook salmon caught downstream of the Stewart River.

		Fishwheels				Commercial		Whitehorse Rapids Fishway		
Year		Male	Female	Unknown	Total	Dawson area	Total	Male	Female	Total
1990	n (#)	904	449	8	1361	10448	11324	898	509	1407
	%	66.4%	33.0%	0.6%				63.8%	36.2%	
1991	n (#)	987	737	2	1726	10416	10906	719	547	1266
	%	57.2%	42.7%	0.1%				56.8%	43.2%	
1992	n (#)	1409	476	4	1889	10306	10877	455	303	758
	%	74.6%	25.2%	0.2%				60.0%	40.0%	
1993	n (#)	921	319	1	1241	9988	10350	384	284	668
	%	74.2%	25.7%	0.1%				57.5%	42.5%	
1994	n (#)	972	322	1	1295	11666	12028	1303	274	1577
	%	75.1%	24.9%	0.1%				82.6%	17.4%	
1995	n (#)	1522	693	0	2215	11044	11146	1391	710	2101
	%	68.7%	31.3%	0.0%				66.2%	33.8%	

Almost all chinook captured in the fishwheels were tagged. During each season from 1990 to 1993 inclusive, chinook that were not tagged numbered less than ten. In 1994 and 1995, 34 and 41 chinook respectively were captured but not tagged. In the latter years samplers did not tag chinook salmon less than 450 mm in length. The number of chinook salmon tagged at the fishwheels from 1990 - 1995 is indicated in Table 18. Table 18 also shows that total numbers of chinook salmon captured varied between fishwheels and between years. From 1992 - 1994 White Rock captured a greater number of fish than did Sheep Rock. In 1990, 1991 and 1995 the converse was observed.

Table 18. Summary of number and sex composition of Yukon River chinook salmon tagged at Sheep Rock and White Rock fishwheels, 1990 - 1995.

		Number and percent sex composition of chinook tagged			
Year	Fishwheel	Male	Female	Unknown	Total
1990	Sheep Rock (n)	613	369	0	982
	Sheep Rock (%)	62.4%	37.6%	0.0%	
	White Rock (n)	291	80	8	379
	White Rock (%)	76.8%	21.1%	2.1%	
	Total (n)	904	449	8	1361
	Total (%)	66.4%	33.0%	0.6%	
		Male	Female	Unknown	Total
1991	Sheep Rock (n)	572	489	1	1062
	Sheep Rock (%)	53.9%	46.0%	0.1%	
	White Rock (n)	415	243	1	659
	White Rock (%)	63.0%	36.9%	0.2%	
	Total	987	732	2	1721
	Total (%)	57.4%	42.5%	0.1%	
		Male	Female	Unknown	Total
1992	Sheep Rock (n)	84	71	0	155
	Sheep Rock (%)	54.2%	45.8%	0.0%	
	White Rock (n)	1325	405	4	1734
	White Rock (%)	76.4%	23.4%	0.2%	
	Total	1409	476	4	1889
	Total (%)	74.6%	25.2%	0.2%	
		Male	Female	Unknown	Total
1993	Sheep Rock (n)	368	173	1	542
	Sheep Rock (%)	67.9%	31.9%	0.2%	
	White Rock (n)	553	146	0	699
	White Rock (%)	79.1%	20.9%	0.0%	
	Total	921	319	1	1241
	Total (%)	74.2%	25.7%	0.1%	
		Male	Female	Unknown	Total
1994	Sheep Rock (n)	442	162	1	605
	Sheep Rock (%)	73.1%	26.8%	0.2%	
	White Rock (n)	497	159	0	656
	White Rock (%)	75.8%	24.2%	0.0%	
	Total	939	321	1	1261
	Total (%)	74.5%	25.5%	0.1%	
		Male	Female	Unknown	Total
1995	Sheep Rock (n)	815	455	20	1290
	Sheep Rock (%)	63.2%	35.3%	1.6%	
	White Rock (n)	659	225	0	884
	White Rock (%)	74.6%	25.5%	0.0%	
	Total	1474	680	20	2174
	Total (%)	67.8%	31.3%	0.9%	

Dates of first fish caught, peak daily count and mid-point of the run at the fishwheels from 1990 - 1995 are presented in Table 19. The mean of these dates for six year cycles preceding the years 1990 -1995 are also presented in Table 19. For the cycle preceding 1990 only a five year mean could be calculated because there was no mark-recapture program in 1984. The date of the peak daily count is the day in a given year on which the greatest number of chinook salmon were captured in the DFO fishwheels. The peak daily counts were 78, 156, 165, 63, 72 and 98 chinook salmon in 1990 - 1995 respectively. The run mid-point is defined as the first date with a cumulative catch greater than 50% of the total catch. Daily and cumulative counts of chinook salmon captured in the Sheep Rock and White Rock fishwheels from 1990 - 1995 are presented in Appendix 4. Figure 2 shows the dates of the first chinook salmon captured at either Sheep Rock or White Rock fishwheels with the 1990 - 1995 mean of June 28. Run timing based on fishwheel catches from 1990 - 1995 is presented with cycle means in Figures 4 - 9.

Table 19. First chinook salmon captured, peak count date and date of run mid-point at the Yukon River Sheep Rock and White Rock tagging fishwheels, 1990 - 1995. Means for six year cycles preceding each year 1990 - 1995 are also presented. For the cycle preceding 1990 only a five year mean could be calculated because there was no mark-recapture program in 1984. This five year mean is identified by an asterix.

	First fish captured in fishwheels						Peak daily count		Mid-point of run	
	Sheep Rock & White Rock		Sheep Rock		White Rock		Sheep Rock & White Rock		Sheep Rock & White Rock	
Year	Day	Week	Day	Week	Day	Week	Day	Week	Day	Week
1990	29-Jun	26	29 June	26	1-Jul	27	19 July & 21 July	29	21 July	29
1991	28-Jun	26	01 July	27	28-Jun	26	06 August	32	25 July	30
1992	14-Jul	29	08 Aug	32	14-Jul	29	22 July	30	26 July	31
1993	23-Jun	26	23 June	26	24-Jun	26	08 July	28	18 July	30
1994	24-Jun	26	01 July	27	24-Jun	26	13 July	29	21 July	30
1995	25-Jun	26	26 June	26	25-Jun	26	27 July	29	26 July	29

	Mean of first fish captured in fishwheels			Mean peak daily count	Mean mid-point of run
Five* or six year cycle	Sheep Rock & White Rock	Sheep Rock	White Rock	Sheep Rock & White Rock	Sheep Rock & White Rock
1985 - 1989*	3-Jul	4-Jul	8-Jul	26-Jul	
1985 - 1990	2-Jul	3-Jul	7-Jul	25-Jul	
1986 - 1991	30-Jun	30-Jun	9-Jul	25-Jul	
1987 - 1992	1-Jul	6-Jul	9-Jul	25-Jul	
1988 - 1993	30-Jun	5-Jul	9-Jul	21-Jul	
1989 – 1994	30-Jun	6-Jul	5-Jul	20-Jul	22-Jul

Tag Recovery

Tag recoveries are presented in Table 20. A low of 23.4% in 1995 and a high of 31.7% in 1992 of the total number of tags applied were recovered. In all years the commercial fishery accounted for over 65% of the total number of recoveries. The aboriginal fishery accounted for between 16.0% (1994) and 29.8% (1992) of the total number of recoveries. A small number of tag recoveries were made in the domestic and recreational fisheries. Some tags were recovered on spawning grounds and some were recovered downstream in Alaska. It is likely that a number of tags were recovered but not returned to DFO. Only commercial fishery tag recoveries were used for the abundance estimates and error associated with these statistics are discussed in the section Pooled Petersen Abundance Estimates, 1990-1995 on page 48.

Table 20. Summary of Yukon River mark-recapture spaghetti tag recoveries from 1990 - 1995. Escapement recoveries were obtained on spawning ground surveys and at the Whitehorse Rapids Fishway. Alaska recoveries were made downstream of the tagging site.

		Total # Recovered		By Fishery or Other Group								
Year	# Tagged			Commercial		Aboriginal		Domestic	Recreational	Escapement	Alaska	Unknown
		(#)	(%)	(#)	(%)	(#)	(%)	(#)	(#)	(#)	(#)	(#)
1990	1361	361	26.5%	236	65.4%	106	29.4%	3	6	8	2	0
1991	1721	521	30.3%	406	77.9%	102	19.6%	1	6	6	0	0
1992	1889	598	31.7%	406	67.9%	178	29.8%	0	2	10	2	0
1993	1241	357	28.8%	246	68.9%	92	25.8%	4	4	8	2	1
1994	1261	362	28.7%	292	80.7%	58	16.0%	2	1	4	0	5
1995	2174	509	23.4%	393	77.2%	104	20.4%	2	5	3	2	0

Commercial Fishery Catches

Yukon River commercial fishery catches in the Dawson area are shown by statistical week in Table 2 along with corresponding catch and effort statistics. Total commercial fishery catches for 1990 - 1995 are presented in Table 31. The number of days between the date the first chinook salmon was captured in the fishwheels and the date of the first opening of the commercial fishery ranged from two days in 1990 to ten days in 1994 (Table 21). A low of 0.22% (1990) and a high of 7.46% (1992) of the total fishwheel catch was captured before the commercial fishery opened (Table 21). In all years, over 98.8% of the total fishwheel catch had been captured by the last day of the last commercial fishery opening.

Table 21. Percentage of total fishwheel catch captured before first opening of commercial fishery, 1990-1995.

Year	Percentage of total fishwheel catch captured before first opening of commercial fishery	Date first chinook captured in fishwheels		First opening of commercial fishery	
		Date	Statistical week	Date	Statistical week
1990	0.22 (3/1361)	29 June, Friday	26	1 July, Sunday	27
1991	0.29 (5/1721)	28 June, Friday	26	1 July, Monday	27
1992	7.46 (141/1889)	14 July, Sunday	25	20 July, Monday	30
1993	1.13 (14/1241)	23 June, Wednesday	26	28 June, Monday	27
1994	2.08 (27/1295)	24 June, Friday	26	4 July, Monday	28
1995	0.68 (15/2215)	25 June, Sunday	26	3 July, Monday	27

BIOLOGICAL CHARACTERISTICS

Sex Composition, Fishwheel and Commercial Samples

The number of female chinook salmon captured in the fishwheels ranged from a low of 24.9% in 1994 to a high of 42.7% in 1991 (Table 17). Only in 1991 did female chinook salmon comprise greater than one third of the total fishwheel catch. Sheep Rock and White Rock fishwheels captured males and females in somewhat similar proportions (Table 18).

The sex composition of the 1995 commercial catch was derived using the commercial biological sample obtained in that year (see the section Sex, Length and Age Sampling on page 8). The weekly sex composition of the 1995 commercial chinook salmon catch sample is presented in Table 22.

Table 22. Weekly sex composition of the commercial chinook salmon catch sample, 1995.

Statistical Week		Male	Female	Total	Catch
27-28	n (#)	99	40	139	2562
	%	71.2%	28.8%		
29	n (#)	198	149	347	2324
	%	57.1%	42.9%		
30	n (#)	171	170	341	2908
	%	50.1%	49.9%		
31	n (#)	153	197	350	2085
	%	43.7%	56.3%		
32	n (#)	53	73	126	987
	%	42.1%	57.9%		
33-36	n (#)	23	26	49	178
	%	46.9%	53.1%		
Total	n (#)	697	655	1352	11044
Exp/ Wt*	n(#)	6019	5025		
Exp/ Wt*	%	54.5%	45.5%		

*Exp/ Wt = expanded/weighted i.e. weekly samples were expanded by catch to produce a weighted total.

The sex composition of chinook salmon at the Whitehorse Rapids Fishway is shown in Table 17. In 1994, a small number of hatchery reared fish were counted more than once. Coded wire tag reading indicated that they had been released as fry at the Whitehorse Rapids Fishway in 1991. This could also have occurred on a smaller scale during the years 1991-1993[6], since fry were released in the fishway in 1989 and 1990, as well as in 1991. The most abundant age class of these fish was likely age 4, which are usually male[7]. Hence the sex ratios presented for the years 1991-1994 may under-represent the true number of females slightly.

Age Composition, Commercial and Fishwheel Samples

Males: From 1990 - 1994 aged 5^2 males comprised the greatest proportion (30.7%, 35.2%, 29.2%, 30.0% and 46.6% respectively) of the total fishwheel catch sample (Table 23). Males aged 4^2 and 6^2 were also caught in relatively high proportions from 1990 - 1994. In 1995 the most frequent age class by sex of chinook captured in the fishwheels was males aged 4^2 (33.4%). In all years 1990 - 1995 aged 5^2 male chinook salmon comprised a greater proportion of the run in early rather than in late statistical weeks (Fig. 9 - Fig. 14). From 1991 - 1995 more aged 4^2 male chinook were captured at the end of the run that at the beginning of the run. Males aged 6^2 were captured with increasing frequency as the run progressed in 1991 (Fig. 10) and more often at the beginning of the run in 1992 and 1995 (Fig. 11 and Fig. 14). Age composition by statistical week for male chinook salmon is presented in Appendix 5.

Females: In all years from 1990 – 1995, age 6^2 was the most frequently captured age class of female chinook salmon (Table 24). In all years except 1993 and 1995 aged 6^2 female chinook were captured with the greatest frequency in the latter half of the run time (Fig. 9 - Fig. 11 and Fig. 13). Conversely, female chinook aged 5^2 comprised a relatively large proportion of the run in early statistical weeks (up to 38.3% in 1991) in all years except 1993 (Fig. 9 - Fig. 11, Fig. 13 and Fig. 14). Age composition by statistical week for female chinook salmon is presented in Appendix 5.

Males and Females Combined: For males and females combined, the major age group of chinook salmon captured in the fishwheels was 5^2 in 1990 (35.8%), 1991 (49.6%), 1993 (33.9%) and 1994 (53.1%) (Table 25). In 1992 and 1995, age 6^2 fish were the most frequent age class captured with percent compositions of 47.9% and 39.2% respectively.

Age composition by statistical week for combined male and female chinook salmon is presented in Appendix 6. In the early statistical weeks of 1990 - 1994 the major age class in fishwheel catches for combined sexes was 5^2 (Appendix 6, Tables 1 to 6). In the latter statistical weeks of 1990, 1991, 1992 and 1994 age class 6^2 was the major age class (Appendix 6, Tables 1 to 3 and 15). This corresponds to the observed increase in catch frequency of age 6^2 females in these years and decrease in catch frequency of age 5^2 males in all years as the run progressed (Fig. 9 - Fig. 14). In 1993 the major age class in the latter statistical weeks was 4^2 (Appendix 6, Table 4). This corresponds to the decrease in catch frequency of age 5^2 males and increase in catch frequency of age 4^2 males as the

[6] Only age-three fish, which are observed infrequently, would have been present in 1991.

[7] In the Yukon, hatchery chinook are more likely to spawn at age four than wild chinook. Age four spawning chinook salmon are usually male (see Section 3.2.2 of this report).

1993 run progressed (Fig. 12). In the early statistical weeks of 1995 the major age class in fishwheel catches of combined sex was 6^2 and this age class remained predominant throughout most of the run (Appendix 6, Table 6). Age class 4^2 chinook were captured with the greatest frequency in statistical weeks 31 and 32 of this year. This corresponds to the consistently high catch frequency of age 6^2 females (Table 24) and the increasing frequency of catch of age 4^2 males in 1995 (Fig. 14).

Appendix 7 presents age composition of the 1995 commercial fishery harvest (males and females combined). As in the 1995 fishwheel catch, age 6^2 was the most frequent age-class encountered. However this age class dominated in the commercial harvest, comprising 71.2% of the total. The contribution of the other age classes was as follows: age 4^2 – 10.5%, age 5^2 – 13.9%, age 7^2 – 4.4% and age 7^3 – 0.1%.

Scale interpretations from fishwheel-caught chinook that could not be completely aged are presented in Appendix 8.

Table 23. Age composition of male chinook salmon captured by Sheep Rock and White Rock fishwheels, 1990 - 1995. All percentages are of the total aged sample, that is including males and females. For example 25.1% of the entire 1990 chinook salmon fishwheel sample that was aged consisted of age 4^2 males. St. Dev. is standard deviation and C.V. is coefficient of variation. The value for the most frequently captured age class in each year is bolded. From 1990 - 1994 aged 5^2 males comprised the greatest proportion of the total fishwheel catch sample. Males aged 4^2 and 6^2 were also caught in relatively high proportions from 1990 - 1994. In 1995 the most frequent age class by sex of chinook captured in the fishwheels was males aged 4^2.

Year		Percent by age class of total aged fishwheel sample												Total males aged	Total males and females aged	Total fishwheel catch
		3^1	3^2	4^1	4^2	5^1	5^2	5^3	6^1	6^2	6^3	7^2	7^3			
1990	n (#)	1	0	1	181	2	221	0	0	72	2	7	1	488	722	1361
	%	0.1%	0.0%	0.1%	25.1%	0.3%	30.7%	0.0%	0.0%	10.0%	0.3%	1.0%	0.1%	67.6%	100.0%	
1991	n (#)	5	0	10	105	7	378	0	0	73	1	21	1	601	1075	1721
	%	0.5%	0.0%	0.9%	9.8%	0.7%	35.2%	0.0%	0.0%	6.8%	0.1%	2.0%	0.1%	55.9%	100.0%	
1992	n (#)	1	0	14	68	4	183	0	0	167	2	3	2	444	627	1889
	%	0.2%	0.0%	2.2%	10.8%	0.6%	29.2%	0.0%	0.0%	26.6%	0.3%	0.5%	0.3%	70.8%	100.0%	
1993	n (#)	11	1	9	225	13	228	1	3	74	1	2	0	568	759	1241
	%	1.4%	0.1%	1.2%	29.6%	1.7%	30.0%	0.1%	0.4%	9.7%	0.1%	0.3%	0.0%	74.8%	100.0%	
1994	n (#)	11	23	17	67	3	387	0	3	96	0	13	0	620	830	1295
	%	1.3%	2.8%	2.0%	8.1%	0.4%	46.6%	0.0%	0.4%	11.6%	0.0%	1.6%	0.0%	74.7%	100.0%	
1995	n (#)	17	5	15	231	10	76	1	0	105	0	11	0	471	692	2215
	%	2.5%	0.7%	2.2%	33.4%	1.4%	11.0%	0.1%	0.0%	15.2%	0.0%	1.6%	0.0%	68.1%	100.0%	
Combined 1990 - 1995																
%		1.0%	0.6%	1.5%	19.5%	0.8%	30.4%	0.0%	0.1%	13.3%	0.1%	1.1%	0.1%	68.7%		
St. Dev.		0.9	1.1	0.8	11.2	0.6	11.5	0.1	0.2	7.1	0.1	0.7	0.1	7.0		
C.V. (%)		91.3%	181.7%	58.0%	57.5%	69.8%	37.9%	155.2%	155.2%	53.1%	99.3%	59.4%	137.0%	10.2%		

Table 24. Age composition of female chinook salmon captured by Sheep Rock and White Rock fishwheels, 1990 - 1995. All percentages are of the total aged sample, that is including males and females. For example 21.2% of the entire 1992 chinook salmon fishwheel sample that was aged consisted of age 6^2 females. St. Dev. is standard deviation and C.V. is coefficient of variation. The value for the most frequently captured age class in each year is bolded. In all years age 6^2 was the most frequently captured age class of female chinook salmon.

Year		Percent by age class of total aged fishwheel sample												Total females aged	Total males and females aged	Total fishwheel catch
		3^1	3^2	4^1	4^2	5^1	5^2	5^3	6^1	6^2	6^3	7^2	7^3			
1990	n (#)	0	0	1	4	3	37	0	0	172	1	16	0	234	722	1361
	%	0.0%	%	0.1%	0.6%	0.4%	5.1%	0.0%	0. %0	**23.9%**	0.1%	2.2%	0.0%	32.4%	100.0%	
1991	n (#)	0	0	4	3	10	155	0	3	240	0	58	1	474	1075	1721
	%	0.0%	0.0%	0.4%	0.3%	0.9%	14.4%	0.0%	0.3%	**22.3%**	0.0%	5.4%	0.1%	44.1%	100.0%	
1992	n (#)	0	0	2	5	5	34	0	1	133	0	4	0	183	627	1889
	%	0.0%	0.0%	0.3%	0.8%	0.8%	5.4%	0.0%	0.2%	**21.2%**	0.0%	0.6%	0.0%	29.2%	100.0%	
1993	n (#)	0	0	0	1	24	29	0	6	111	0	20	0	191	759	1241
	%	0.0%	0.0%	0.0%	0.1%	3.2%	3.8%	0.0%	0.8%	**14.6%**	0.0%	2.6%	0.0%	25.2%	100.0%	
1994	n (#)	0	0	0	0	12	54	0	5	117	0	20	2	210	830	1295
	%	0.0%	0.0%	0.0%	0.0%	1.4%	6.5%	0.0%	0.6%	**14.1%**	0.0%	2.4%	0.2%	25.3%	100.0%	
1995	n (#)	0	1	3	3	11	23	0	1	166	0	12	1	221	692	2215
	%	0.0%	0.1%	0.4%	0.4%	1.6%	3.3%	0. %0	0.1%	**24.0%**	0.0%	1.7%	0.1%	31.9%	100.0%	
Combined 1990 - 1995																
%		0.0%	0.0%	0.2%	0.4%	1.4%	6.4%	0.0%	0.3%	**20.0%**	0.0%	2.5%	0.1%	31.3%		
St. Dev.		0.0	0.1	0.2	0.3	1.0	4.1	0.0	0.3	4.5	0.1	1.6	0.1	7.0		
C.V. (%)		0.0%	244.9%	90.5%	79%.4	69.7%	63.3%	0.0%	92.2%	22.5%	244.9%	63.2 %	124.7%	22.3%		

Table 25. Age composition by year of combined male and female chinook salmon catches at Sheep Rock and White Rock fishwheels, 1990 - 1995. St. Dev. is standard deviation and C.V. is coefficient of variation. The value for the most frequently captured age class in each year is bolded. For males and females combined the major age group of chinook salmon captured in the fishwheels was 5^2 in 1990, 1991, 1993 and 1994 and 6^2 in 1992 and 1995.

Year		Percent by age class 3^1	3^2	4^1	4^2	5^1	5^2	5^3	6^1	6^2	6^3	7^2	7^3	Total aged	Total fishwheel catch
1990	n (#)	1	0	2	185	5	258	0	0	244	3	23	1	722	1361
	%	0.1%	0.0%	0.3%	25.7%	0.7%	**35.8%**	0.0%	0.0%	33.8%	0.4%	3.2%	0.1%	100.00%	
1991	n (#)	5	0	14	108	17	533	0	3	313	1	79	2	1075	1721
	%	0.5%	0.0%	1.3%	10.1%	1.6%	**49.6%**	0.0%	0.3%	29.1%	0.1%	7.4%	0.2%	100.00%	
1992	n (#)	1	0	16	73	9	217	0	1	300	2	7	2	627	1889
	%	0.2%	0.0%	2.6%	11. 6%	1.4%	34.6%	0.0%	0.2%	**47.9%**	0.3%	1.1%	0.3%	100.00%	
1993	n (#)	11	1	9	226	37	257	1	9	185	1	22	0	759	1241
	%	1.5%	0.1%	1.2%	29.8%	4.9%	**33.9%**	0.1%	1.2%	24.4%	0.1%	2.9%	0.0%	100.00%	
1994	n (#)	11	23	17	67	15	441	0	8	213	0	33	2	830	1295
	%	1.3%	2.8%	2.1%	8.1%	1.8%	**53.1%**	0.0%	1.0%	25.7%	0.0%	4.0%	0.2%	100.00%	
1995	n (#)	17	6	18	234	21	99	1	1	271	0	23	1	692	2215
	%	2.5%	0.9%	2.6%	33.8%	3.0%	14.3%	0.1%	0.1%	**39.2%**	0.0%	3.3%	0.1%	100.00%	
Combined 1990 - 1995															
%		1.0%	0.6%	1.7%	19.8%	2.2%	**36.9%**	0.1%	0.5%	33.3%	0.2%	3.6%	0.2%		
St. Dev.		0.9	1.1	0.9	11.2	1.5	13.8	0.1	0.5	8.96	0.2	2.0	0.1		
C.V. (%)		91.3%	175.5%	54.5%	56.6%	67.0%	37.4%	155.2%	108.2%	26.9%	107.3%	56.4%	62.8%		

Length Composition

Mean fork length-at-age for 1990 - 1995 ranged from 497.7 mm (19.1% C.V., 412.2 mm - 600.0 mm, n = 29) (age 3^2) to 995.0 mm (0.7% C.V., 990.0 mm - 1000.0 mm, n = 6) (age 6^1) for males (Table 26). For females it ranged from 510.0 mm (n = 1) (age 3^2) to 948.4 mm (3.6% C.V., 882.5 mm - 975.0 mm, n = 260) (age 7^2) (Table 27). Mean fork length from 1990 - 1995 was greater for females than for males in all age classes 5^2 or younger. For chinook salmon older than age 5^2, mean fork length was greater in males than in females. Mean length increased with age class within groups of male or female chinook salmon that migrated to the ocean after the same number of years in freshwater (Table 26 and Table 27). For example, mean length was greater in age class 6^1 than in age class 5^1 for both male and female chinook salmon. Mean length decreased with increasing number of years spent in freshwater for both male and female chinook salmon (Table 26 and Table 27). For example mean length was greater in age class 5^1 than in age class 5^2.

The mean length-at-age for males and females remained consistent from 1990 - 1995 (Table 26 and Table 27). For males all coefficients of variation for mean length-at-age were under 10% with the exception of those for male age classes 3^1, 3^2 and 7^2 which had very small sample sizes (maximum 17) and coefficients of variation of 19.3%, 19.1% and 13.7% respectively. The highest coefficient of variation for female mean length-at-age was 6.7% for the small sample size age groups 4^1 and 4^2.

The age class containing chinook salmon with the largest mean length was that of age 6^1 males (Table 26). However the proportion of the run comprised by this male length-at-age class was 0.0% in all years 1990 - 1995 except 1993 and 1994 in which it was 0.4%. The mean fork length from 1990 - 1995 for age 7^2 male chinook salmon was also high at 983.3 mm (13.7 % C.V., 710.0 mm - 1050.0 mm, n = 57) (Table 26). The proportion of the run comprised by age 7^2 male chinook salmon ranged from 0.5% in 1992 and 1993 to 2.0% in 1991 and 1995. The mean length for the age class comprising the greatest proportion of the run ranged from 744.0 mm to 816.4 mm in age 5^2 males for the years 1990 - 1994 and was 597.7 mm for age 4^2 males in 1995 (Table 23 and Table 26).

The length histograms in Figures 16 - 23 show that whereas a large proportion of the female chinook salmon captured in each year were within a relatively small range of lengths, the male chinook salmon catch consisted of a greater range of lengths captured in smaller proportions. Specifically, large chinook salmon comprised a greater proportion of the total female catch than of the total male catch. Although the relationship was not examined, the length composition of chinook salmon captured in the fishwheels likely changed in conjunction with the changing age composition as the run progressed. The commercial fishery catch sample consisted of a greater proportion of both male and female large size chinook salmon than did the fishwheel catch (Fig. 20 - Fig. 23). This corresponds with the significant results of chi-square testing for capture selectivity that are presented in the section Adjustments for Capture Selectivity on page 35.

The weekly length (fork length only) composition of the 1995 commercial chinook salmon catch sample is presented in Table 28.

Table 26. Mean fork length by age class of male Yukon River chinook salmon captured in Sheep Rock and White Rock fishwheels, 1990 - 1995. St. Dev. is standard deviation and C.V. is coefficient of variation.

		Fork Length By Age Class											
Year		3^1	3^2	4^1	4^2	5^1	5^2	5^3	6^1	6^2	6^3	7^2	7^3	Total
1990	N	1	0	1	181	2	221	0	0	72	2	7	1	488
	Length	520.0		750.0	619.8	865.0	751.1			885.8	815.0	1004.3	900.0	
1991	N	5	0	10	105	7	378	0	0	73	1	21	1	601
	Length	504.0		737.0	589.4	830.0	782.4			935.6	780.0	1045.2	880.0	
1992	N	1	0	14	68	4	183	0	0	167	2	3	2	444
	Length	790.0		807.9	736.5	817.5	816.4			818.4	875.0	710.0	775.0	
1993	N	11	1	9	225	13	228	1	3	74	1	2	0	568
	Length	537.9	600.0	726.7	584.9	858.5	744.0	600.0	990.0	882.0	850.0	1050.0		
1994	N	11	23	17	67	3	387	0	3	96	0	13	0	620
	Length	503.6	412.2	708.2	583.7	903.3	756.5		1000.0	899.7		1043.8		
1995	N	17	5	15	231	10	76	1	0	105	0	11	0	471
	Length	563.8	481.0	692.0	597.7	846.0	742.0	630.0		881.2		1046.4		
1990 – 1995 Mean		569.9	497.7	737.0	618.7	853.4	765.4	615.0	995.0	883.8	830.0	983.3	851.7	
St. Dev.		110.2	95.0	40.4	59.2	30.1	28.9	21.2	7.1	38.0	41.4	134.9	67.1	
C.V. (%)		19.3%	19.1%	5.5%	9.6%	3.5%	3.8%	3.4%	0.7%	4.3%	5.0%	13.7%	7.9%	

Table 27. Mean fork length by age class of female Yukon River chinook salmon captured in Sheep Rock and White Rock fishwheels, 1990 - 1995. St. Dev. is standard deviation and C.V. is coefficient of variation.

		Fork Length By Age Class										
Year		3^1	3^2	4^1	4^2	5^1	5^2	6^1	6^2	6^3	7^2	7^3	Total
1990	N	0	0	1	4	3	37	0	172	1	16	0	234
	Length			760.0	640.0	870.0	784.3		900.8	810.0	950.6		
1991	N	0	0	4	3	10	155	3	240	0	58	1	474
	Length			775.0	650.0	830.0	788.3	893.3	897.5		970.5	830.0	
1992	N	0	0	2	5	5	34	1	133	0	4	0	184
	Length			865.0	694.0	914.0	847.6	870.0	807.1		882.5		
1993	N	0	0	0	1	24	29	6	111	0	20	0	191
	Length				600.0	889.6	792.8	928.3	888.2		975.0		
1994	N	0	0	0	0	12	54	5	117	0	20	2	210
	Length					865.0	770.7	912.0	906.3		959.0	870.0	
1995	N	0	1	3	3	11	23	1	166	0	12	1	221
	Length		510.0	748.3	586.7	864.5	822.0	1020.0	893.5		952.5	850.0	
1990 - 1995 Mean			510.0	787.1	634.1	872.2	801.0	924.7	882.2	810.0	948.4	850.0	
St. Dev.				53.1	42.7	28.1	28.4	57.5	37.3		33.7	20.0	
C.V. (%)				6.7%	6.7%	3.2%	3.5%	6.2%	4.2%		3.6%	2.4%	

Table 28. Weekly length composition of the commercial chinook salmon catch sample, 1995.

Statistical Week		Fork length (mm) < 800	800 – 899	900 - 999	> 999	Total
28	n (#)	43	33	41	22	139
	%	30.9%	23.7%	29.5%	15.8%	
29	n (#)	60	82	149	57	348
	%	17.2%	23.6%	42.8%	16.4%	
30	n (#)	41	76	140	84	341
	%	12.0%	22.3%	41.1%	24.6%	
31	n (#)	73	62	128	87	350
	%	20.9%	17.7%	36.6%	24.9%	
32	n (#)	10	21	52	43	126
	%	7.9%	16.7%	41.3%	34.1%	
33	n (#)	4	3	20	22	49
	%	8.1%	6.1%	40.8%	44.9%	
Total	n (#)	231	277	530	315	1353
	%	17.1%	20.5%	39.2%	23.3%	

Length Conversions

Linear regression was used to determine the relationship between POH length and fork length measurements in the 1995 commercial fishery sample. Females and males were treated seperately. Relationships for each were significant ($p<0.05$) and had the same r-square (0.93). They were as follows:

Females: $POH = 0.764*FL + 43.595$.

Males: $POH = 0.733*FL + 55.605$.

ABUNDANCE ESTIMATES

Adjustments for Capture Selectivity

In 1990, 1992, 1993 and 1995 female chinook comprised a greater proportion of the total tagged and sexed commercial fishery catch than of the total fishwheel catch that was tagged and released (Table 29). In all years 1990 to 1995 large chinook comprised a greater proportion of the tagged and measured commercial fishery catch than of the fishwheel catch that was tagged and released (Table 30).

Table 29. Numbers of chinook salmon of known sex tagged and released at the fishwheels and recaptured in the commercial fishery and results of corresponding chi-square tests for within year differences in release and recapture sample sex compositions ($\chi^2_{(crit.)} = 3.841$, df = 1, p = 0.05). Significant results are bolded. Total numbers of Yukon River chinook salmon tagged and released at the fishwheels do not include fish of unknown sex. This is a test for gear selectivity and not indicative of the sex composition in the Yukon River chinook salmon population. Recapture sample numbers were not adjusted to account for tag loss.

		Tagged Yukon River chinook salmon				Chi-square test results	
Year		Male (#)	Female (#)	Total (#)	Female (%)	$\chi^2_{2(obs.)}$	$\chi^2_{2(crit.)}$ at p = 0.05
1990	Release	904	449	1353	33.19%	**12.008**	3.841
	Recapture	132	103	235	43.83%		
1991	Release	987	732	1719	42.58%	2.439	3.841
	Recapture	217	188	405	46.42%		
1992	Release	1409	476	1885	25.25%	**4.589**	3.841
	Recapture	284	121	405	29.88%		
1993	Release	921	319	1240	25.73%	**9.395**	3.841
	Recapture	161	84	245	34.29%		
1994	Release	939	321	1260	25.48%	0.270	3.841
	Recapture	213	78	291	26.80%		
1995	Release	1474	680	2154	31.57%	**37.879**	3.841
	Recapture	211	180	391	46.04%		

Table 30. Numbers of tagged chinook salmon of known length tagged and released at the fishwheels and recaptured in the commercial fishery and results of corresponding chi-square tests for within year differences in release and recapture sample length classes ($\chi^2_{(crit.)} = 7.815$, df = 3, p = 0.05). Significant results are bolded. Total numbers of tagged Yukon River chinook salmon released do not include fish of unknown length. Note that this is a test for gear selectivity and not indicative of the length class composition in Yukon River chinook salmon population. Recapture sample numbers were not adjusted to account for tag loss.

		Number of tagged Yukon River chinook salmon,					Chi-square test results	
Year		< 800	800 - 899	900 - 999	> 999	Total	$\chi^2_{3(obt.)}$	$\chi^2_{3(crit.)}$ at p = 0.05
1990	Release	706	340	228	79	1353	**37.973**	7.815
	Recapture	82	71	60	22	235		
1991	Release	714	605	300	100	1719	**91.523**	7.815
	Recapture	107	137	119	42	405		
1992	Release	1070	381	313	120	1884	**43.020**	7.815
	Recapture	181	85	105	33	404		
1993	Release	751	279	134	74	1238	**51.950**	7.815
	Recapture	105	68	52	19	244		
1994	Release	705	300	162	93	1260	**44.287**	7.815
	Recapture	120	76	60	35	291		
1995	Release	1158	568	320	108	2154	**114.182**	7.815
	Recapture	123	129	98	41	391		

Pooled Petersen Abundance Estimates, 1990 – 1995

Chinook salmon pooled Petersen abundance estimates for the years 1990 - 1995 are presented in Table 31 with the mark-recapture data used to derive them and with 95% confidence intervals. The highest estimate of 56,679 chinook salmon in 1990 is 37.6% greater than the lowest estimate of 41,187 chinook salmon in 1991. In all years the upper and lower 95% confidence limits were within 9.2% and 13.9% of the abundance estimate.

Petersen abundance estimates for 1995 that were calculated by summing separate estimates by sex and length class are presented in Table 32. The estimate by sex is 54,305 which is 3.7% higher than the combined 1995 Petersen estimate of 52,353. The estimate by length is 44,485 which is 15.0% lower than the combined 1995 Petersen estimate. Petersen abundance estimates for 1995 are also presented in the summary Table 33.

Table 31. Pooled Petersen abundance estimates for 1990 - 1995 Yukon River chinook salmon with upper and lower limits for 95% confidence levels and with the corresponding mark-recapture data required for estimate calculation. Tag recoveries (*R*) and catches associated with tags (*C*) were from chinook salmon captured in the Yukon River below the confluence with the Stewart River. Yukon River basin catches include catches in all tributaries of the Yukon River. Total aboriginal, domestic and recreational catches are estimates.

	Pooled Petersen Estimate		Spawning Escapement Estimate		Petersen Equation Parameters				Yukon River basin catches				
Year	Estimate	Upper & Lower 95% Confidence Limits	Estimate	Upper and Lower 95% Confidence Limits	Tags recovered (*R*)	Total catch associated with tags (*C*)	Total number of tags applied	Total tags applied assuming 10% loss (*M*)	Total commercial catch	Total aboriginal catch	Total domestic catch	Total recreational catch	Total catch
1990	56679	64546 49768	37699	45566 30788	225	10448	1361	1224.9	11324	7109 (est)	247 (est)	300 (est)	18980
1991	41187	45465 37311	20743	25021 16867	391	10461	1721	1548.9	10906	9011 (est)	227 (est)	300 (est)	20444
1992	43185	47589 39188	25382	29786 21385	405	10306	1889	1700.1	10877	6349 (est)	277 (est)	300 (est)	17803
1993	45027	50977 39769	28558	34508 23300	247	9988	1241	1116.9	10350	5576 (est)	243 (est)	300 (est)	16469
1994	45231	50704 40346	24441	29914 19556	292	11666	1261	1134.9	12028	8089 (est)	373 (est)	300 (est)	20790
1995	52353	57644 47546	32262	37553 27455	412	11044	2174	1956.6	11146	7945 (est)	300 (est)	700 (est)	20091

Table 32. Pooled Petersen abundance estimates by sex (A) and by length (B) for 1995 Yukon River chinook salmon with upper and lower limits for 95% confidence levels and with the corresponding mark-recapture data required for estimate calculation. Tag recoveries (*R*) and catches associated with tags (*C*) were from chinook salmon captured in the Yukon River below the confluence with the Stewart River. Yukon River basin catches include catches in all tributaries of the Yukon River.

A.

		Pooled Petersen Estimate		Petersen Equation Parameters			
Sex	Estimate	Upper & Lower 95% Confidence Limits	Percent difference from estimate (%)	Tags recovered (*R*)	Total catch associated with tags (*C*)	Total number of tags applied	Total tags applied assuming 10% loss (*M*)
Male	37490	42860	14.3%	212	6018	1473	1325.7
		32791	12.5%				
Female	16814	19425	15.5%	182	5026	679	611.1
		14553	13.4%				
Total	**54305**						

B.

		Pooled Petersen Estimate		Petersen Equation Parameters			
Length	Estimate	Upper & Lower 95% Confidence Limits	Percent difference from estimate (%)	Tags recovered (*R*)	Total catch associated with tags (*C*)	Total number of tags applied	Total tags applied assuming 10% loss (*M*)
< 800 mm	17389	20715	19.1%	123	2066	1158	1042.2
		14595	16.1%				
800 - 899 mm	9271	11000	18.6%	129	2348	569	512.1
		7813	15.7%				
900 - 999 mm	12037	14622	21.5%	99	4190	318	286.2
		9905	17.7%				
> 999 mm	5788	7787	34.5%	41	2452	109	98.1
		4293	25.8%				
Total	**44485**						

Table 33. Summary table of 1995 Yukon River chinook salmon abundance estimates. Confidence limits could only be calculated for the combined pooled Petersen and Darroch estimates. The estimates marked (*) fall within the confidence limits of the pooled Petersen estimate.

	Type Combined		By sex	By length
Estimate		Confidence Limits		
Pooled Petersen	52353	57644 47546	54305*	44485
Schaefer	57675	n/a n/a	59598	48712*
Darroch	55524*	61375 49674*	55696*	47407

Table 34. Summary table of percent differences between 1995 Yukon River chinook salmon abundance estimates. Percent differences are of the estimates in the first column relative to the estimates in the top row. For example, the combined Schaefer estimate is 10.2% higher than the combined Petersen estimate.

	Are higher or lower than estimates in this row:						
Estimates in this column:	Combined Petersen	Petersen by sex	Petersen by length	Combined Schaefer	Schaefer by sex	Schaefer by length	Combined Darroch
Combined Petersen							
Combined Schaefer	10.2% higher						
Combined Darroch	6.1% higher			3.7% lower			
Petersen by sex	3.7% higher						
Schaefer by sex	13.8% higher	9.7% higher		3.3% higher			
Darroch by sex	6.4% higher	2.6% higher			6.5% lower		0.3% higher
Petersen by length	15.0% lower						
Schaefer by length	6.9% lower		9.5% higher	15.5% lower			
Darroch by length	9.4% lower		6.6% higher			2.7% lower	14.6% lower

Schaefer Estimates For Stratified Populations, 1995

The Schaefer method provides estimates of the portion of the population available for marking in period *i* of tagging and release *and* available for recapture in period *j* of fishing. The 1995 Schaefer abundance estimates are presented in Table 35. Weekly estimates at the points of tagging and recapture are presented in Table 36 – Table 41. The abundance estimate for sexes and length classes combined is 57,675 which is 10.2% higher than the 1995 combined Petersen estimate of 52,353. The total abundance estimate derived from separate sex calculations is 59,598 which is approximately 3.3% higher than the combined Schaefer estimate and 13.8% higher than the combined Petersen estimate. The total abundance estimate derived from separate length calculations is 48,712 which is approximately 6.9% lower than the Petersen estimate.

Table 35. Schaefer abundance estimates for 1995 Yukon River chinook salmon, calculated for combined and separate sexes and length classes.

Combined Schaefer Abundance estimate	Schaefer abundance estimate by sex		Schaefer abundance estimate by length class	
	Sex	Abundance estimate	Length class (mm)	Abundance estimate
57675	Male	41962	< 800	19820
	Female	17636	800 - 899	10140
	Total	**59598**	900 - 999	12811
			> 999	5941
			Total	**48712**

Table 36. Schaefer abundance estimates by statistical week of tagging and recapture for 1995 Yukon River male chinook salmon.

Statistical week tag applied	Recapture week						Total
	27-28	29	30	31	32	33-36	
26 - 27	8506	0	0	0	0	0	8506
28	7548	3461	0	73	0	0	11082
29	0	4884	2798	87	0	0	7769
30	0	0	6026	2811	225	0	9061
31	0	0	0	2302	1505	0	3807
32	0	0	0	0	755	402	1156
33 - 36	0	0	0	0	0	579	579
Total	16055	8345	8824	5273	2484	980	41962

Table 37. Schaefer abundance estimates by statistical week of tagging and recapture for 1995 Yukon River female chinook salmon.

Statistical week tag applied	Recapture week						Total
	27-28	29	30	31	32	33-36	
26 - 27	1581	139	0	0	0	0	1721
28	1801	1232	0		0	0	3033
29	0	1739	1822	0	0	0	3561
30	0	0	2942	2560	320	0	5823
31	0	0	0	1289	645	0	1934
32	0	0	0	0	648	175	823
33 - 36	0	0	0	0	0	741	741
Total	3382	3110	4764	3849	1614	916	17636

Table 38. Schaefer abundance estimates by statistical week of tagging and recapture for 1995 Yukon River chinook salmon < 800 mm in fork length.

	Recapture week						
Statistical week tag applied	27-28	29	30	31	32	33-36	Total
26 - 27	5584	0	0	0	0	0	5584
28	3493	1493	0	82	0	0	5067
29	0	2049	919	82	0	0	3050
30	0	0	2065	1824	30	0	3919
31	0	0	0	1434	349	0	1782
32 - 36	0	0	0	0	261	158	418
Total	9076	3541	2984	3422	640	158	19820

Table 39. Schaefer abundance estimates by statistical week of tagging and recapture for 1995 Yukon River chinook salmon 800 - 899 mm in fork length.

	Recapture week						
Statistical week tag applied	27-28	29	30	31	32	33-36	Total
26 - 27	1548	175	0	0	0	0	1723
28	1803	949	0	0	0	0	2752
29	0	1073	1155	0	0	0	2228
30	0	0	1407	955	122	0	2485
31	0	0	0	444	243	0	687
32 - 36	0	0	0	0	223	42	265
Total	3351	2197	2562	1400	588	42	10140

Table 40. Schaefer abundance estimates by statistical week of tagging and recapture for 1995 Yukon River chinook salmon 900 - 999 mm in fork length.

	Recapture week						
Statistical week tag applied	27-28	29	30	31	32	33-36	Total
26 - 27	1166	0	0	0	0	0	1166
28	1477	928	0	0	0	0	2406
29	0	2043	1124	0	0	0	3167
30	0	0	2703	1150	126	0	3979
31	0	0	0	855	374	0	1228
32	0	0	0	0	455	60	515
33 - 36	0	0	0	0	0	350	350
Total	2644	2971	3827	2005	955	410	12811

Table 41. Schaefer abundance estimates by statistical week of tagging and recapture for 1995 Yukon River chinook salmon > 999 mm in fork length.

	Recapture week					
Statistical week tag applied	27-28	29	30	31	32-36	Total
26 - 28	932	398	0	0	0	1330
29	0	347	133	0	0	480
30	0	0	1295	793	352	2439
31 - 36	0	0	0	564	1128	1692
Total	932	746	1427	1357	1479	5941

Darroch Estimates for Stratified Populations, 1995

The 1995 Darroch chinook salmon abundance estimate for the combined mark-recapture sample is 55,524 (Table 33). Upper and lower confidence limits are 61,375 and 49,674 and are within 10.5% of the estimate. This estimate is 6.1% higher than the combined pooled Petersen estimate of 52,353. The 1995 Darroch abundance estimates by sex and by length are presented in Table 42 and Table 43. The total abundance estimate derived from separate sex calculations is 55,696 which is 6.4% higher than the combined pooled Petersen estimate of 52,353 and 6.5% lower than the Schaefer estimate by sex of 59,598. The confidence limits for the separate male and female Darroch estimates are +/-16.2% and +/-18.6% respectively. The total abundance estimate derived from separate length calculations is 47,407. This is 9.4% lower than the combined pooled Petersen estimate of 52,353 and 2.7% lower than the Schaefer estimate by length of 48,712. The confidence limits for the separate estimates by length range from +/-17.3% to +/-23.7%.

Table 42. Darroch abundance estimates for 1995 Yukon River chinook salmon, calculated for separate sexes and with upper and lower 95% confidence limits.

Darroch abundance estimate by sex		95% Confidence limits		
Sex	Abundance estimate	Lower	Upper	Difference from estimate (%)
Male	38823	32538	45107	16.2%
Female	16873	13730	20017	18.6%
Total	**55696**			

Table 43. Darroch abundance estimates for 1995 Yukon River chinook salmon, calculated for separate length classes and with upper and lower 95% confidence limits.

Darroch abundance estimate by length		95% Confidence limits		
Length Class (mm)	Abundance estimate	Lower	Upper	Difference from estimate (%)
< 800	18563	14414	22712	22.4%
800 - 899	9636	7972	11300	17.3%
900 - 999	13418	10531	16304	21.5%
> 999	5790	4419	7161	23.7%
Total	**47407**			

CATCHES IN ABORIGINAL, DOMESTIC AND RECREATIONAL FISHERIES AND SPAWNING ESCAPEMENT

Catches in aboriginal, domestic and recreational fisheries and spawning escapement are presented in Table 31 along with Petersen estimates (see the section Pooled Petersen Abudance Estimates on page 37). Catches in all three of these fisheries are estimates. The estimates of total aboriginal chinook salmon catches ranged from 5,576 in 1993 to 9,011 in 1991. The estimates of total domestic chinook salmon catches ranged from 227 in 1991 to 373 in 1994. Total recreational catches of chinook salmon were estimated at 300 annually from 1990 – 1994 and at 700 in 1995. There is a difference of have 16,956 fish between the lowest spawning escapement estimate of 20,743 in 1991 and the highest spawning escapement estimate of 37,699 in 1990 (Appendix 2). These years correspond to years in which the low and high pooled Petersen abundance estimates were observed.

HARVEST RATES

The mean harvest rate (i.e. total catch/border escapement) from 1990 - 1995 for all fisheries on the Canadian portion of the Yukon River ranged from 33.5% (1990) to 49.6% (1991) with a mean of 40.9% (standard deviation 6.0%) (Table 44). The mean commercial fishery harvest rate from 1990 - 1995 was 23.8% and for the same time period the mean aboriginal, domestic and recreational fishery harvest rates were 15.8%, 0.6% and 0.8% respectively. These harvest rates were calculated using the border escapement (pooled Petersen abundance estimate) as the total stock vulnerable to a given fishery and therefore do not take into account removal of chinook salmon from the catchable population by fisheries situated farther downstream. The border escapement refers to all chinook salmon that migrate past the Yukon - Alaska international border (Fig. 1). Bromaghin (1990) suggested that the exploitation rate for the commercial fishery should be estimated within strata when there is an assumption that the probability of recapture is equal for all members of a stratum but may be different between strata.

Table 44. Chinook salmon harvest rates for all fisheries in the Canadian portion of the Yukon River basin, 1990 - 1995. Border escapement is the pooled Petersen abundance estimate. C.V. is coefficient of variation.

		Harvest Rate (%)				
Year	Border escapement	Commercial	Aboriginal	Domestic	Recreational	Total
1990	56679	20.0%	12.5%	0.4%	0.5%	33.5%
1991	41187	26.5%	21.9%	0.6%	0.7%	49.6%
1992	43185	25.2%	14.7%	0.6%	0.7%	41.2%
1993	45027	23.0%	12.4%	0.5%	0.7%	36.6%
1994	45231	26.6%	17.9%	0.8%	0.7%	46.0%
1995	52353	21.3%	15.2%	0.6%	1.3%	38.4%
Mean 1990-1995	47277	23.8%	15.8%	0.6%	0.8%	40.9%
Standard Deviation	5953.9	2.8	3.6	0.1	0.3	6.0
C.V. (%)	12.6	11.7%	22.9%	22.0%	37.2%	14.8%

ESCAPEMENT INDEX SURVEYS

Table 45 presents annual spawning ground index survey and Whitehorse Rapids Fishway counts from 1990 - 1995. Surveys that were given a rating of incomplete or poor (for example Ross River 1995 and 1990) were excluded from the analysis conducted to assess if there is a relationship with mark-recapture results. Likewise, the 1990 Wolf River count was excluded because the index area in that year differed slightly from the area surveyed from 1991 to 1995. Due to the necessity of excluding some counts, yearly means instead of yearly totals were used. Regression analysis indicated that a significant relationship at a 95% confidence level does not exist.

Table 45. Chinook salmon escapement index counts for selected spawning areas in the Canadian portion of the Yukon River drainage, 1990 - 1995. Means of creek and river counts include counts from the seven creeks and rivers listed below and not from the Whitehorse Rapids Fishway.

Year	Tincup Creek (a)	Tatchun Creek (a, b)	Little Salmon River (a)	Big Salmon River (a, c)	Nisutlin River (a, d)	Ross River (a, f)	Wolf River (a)	Mean of creek and river counts	Whitehorse Rapids Fishway (h)	Yukon Spawning Escapement (j)
1990	83	643	665	1806	652	457 (k)	188 (g)	769.8	1407	37699
1991			326	1040		250	201 (r)	454.25	1266	20743
1992	73	106	494	617	241	423	110 (r)	294.86	758	25382
1993		183	184	572	339	400	168 (r)	307.67	668	28558
1994	101 (k)	477	726	1764	389	506	393 (r)	709.17	1577	24441
1995	121	397	781	1314	274	253 (k)	229 (r)	519.33	2103	32262

Legend

a Data obtained by aerial survey unless otherwise noted. Only peak counts are listed. Survey rating is fair to good, unless otherwise noted.
b All foot surveys.
c From the mainstem Big Salmon River between Big Salmon Lake and the vicinity of Souch Creek.
d Hundred Mile Creek to Sidney Creek.
f Big Timber Creek to Lewis Lake.
g Wolf Lake to Red River.
h Counts from 1991 to 1994 inclusive may overestimate escapement slightly since some adipose-fin-clipped salmon were counted more than once.
j Estimated total spawning escapement excluding Porcupine River (estimated border escapement minus the Canadian catch).
k Incomplete and/ or poor survey resulting in minimal or inaccurate counts.
r Counts are for Wolf Lake to Fish Lake outlet.

MIGRATION RATES

The mean migration rates from 1990 - 1995 increased with distance of recapture location from the fishwheels (Table 46). The mean chinook salmon migration rates from 1990 - 1995 were 18.48 km/day (5.8% C.V., 17.04 km/ day - 19.75 km/ day) for fish recaptured between the Yukon - Alaska border and the Forty Mile River, 30.99 km/ day (19.68 % C.V., 24.20 km/ day - 38.43 km/ day) for fish recaptured between the Forty Mile River and the Stewart River and 37.07 km/ day (8.63 % C.V., 33.42 km/ day - 40.49 km/ day) for fish recaptured at the Whitehorse Rapids Fishway.

Behavioural changes in response to tagging stress likely account in part for the apparent slower migration rates calculated in the recapture locations closest to the fishwheels (Table 46). In general, the recapture sample migration rate mean may be less than that of the true abundance mean since tagging stress probably causes chinook salmon to alter, slow down or temporarily halt migration. The effect of tagging stress is discussed in detail in the section Pooled Petersen Abundance Estimates, 1990-1995 on page 48. Lack of precision in recording the time of recapture may also contribute to variation in the calculated migration rates.

Table 46. Migration rates of Yukon River chinook salmon tagged in Sheep Rock and White Rock fishwheels and recaptured in the commercial fishery (*) or at the Whitehorse Rapids Fishway, 1990 - 1995. C.V. is coefficient of variation.

	Location of recapture		
	Tagging Sites to Forty Mile River *	Forty Mile River to Stewart River *	Whitehorse Rapids Fishway
Year	Migration rate (km/day)		
1990	18.77	24.48	33.61
1991	17.04	24.20	33.42
1992	19.30	32.40	40.49
1993	18.67	29.33	40.27
1994	19.75	37.10	38.70
1995	17.32	38.43	35.94
Mean	18.48	30.99	37.07
Std. Dev.	1.08	6.10	3.20
C.V.%	5.84%	19.68%	8.63%

OTHER SPECIES

Indigenous species were captured by both Sheep Rock and White Rock fishwheels. The species captured between 1990-95 included burbot (*Lota lota*), lake whitefish (*Coregonus clupeaformis*), longnose sucker (*Catostomus catostomus*), Arctic cisco (*Coregonus autumnalis*), Arctic grayling (*Thymallus arcticus*) and inconnu (*Stenodus leucichthys*). Actual numbers of indigenous species captured were not recorded since recapture was frequent and it was difficult to determine how many times it occurred for a particular fish. Coho salmon (*Oncorhynchus kisutch*) were captured in the fishwheels and in the commercial fishery in 1992. The adult spawning return migration of chum salmon up the Yukon River is documented in other reports.

DISCUSSION

The major criticisms of mark-recapture methodology usually concern the violation of assumptions and the imprecision of estimates (wide confidence intervals) (Dempson & Stansbury (1991). This section addresses these problems with respect to the pooled Petersen, Schaefer and Darroch estimators. Arnason et al. (1996) provide an excellent review of population estimators.

POOLED PETERSEN ABUNDANCE ESTIMATES, 1990 – 1995

Some of the major assumptions underlying the pooled Petersen estimate are:

1. The marked fish do not lose their mark;
2. The survival and behaviour of marked and unmarked fish is the same;
3. Either or both the captures for marking and the recaptures are random; that is all fish have the same probability of being marked and/ or all fish tagged and untagged have the same probability of being captured in the recovery sample, or there is uniform mixing of tagged and untagged fish;
4. The population is closed; i.e. there is only a negligible amount of loss from or recruitment to the catchable abundance during the time the recoveries are being made;
5. All marks are recognised and reported on recovery;

The extent to which these assumptions are satisfied or violated in the DFO Yukon River chinook salmon program has been considered by Brannian (1990) and examined in detail by Bromaghin (1990).

Assumption 1. The marked fish do not lose their mark.

The effect of unchecked tag loss is to reduce the value of the *R* parameter in the Petersen mark-recapture equation and augment the abundance estimate (positive bias). The extent of tag loss in the Yukon River chinook salmon mark-recapture program has not been thoroughly examined. Tag loss due to physical breakage of the tag could occur as a result of catching on natural objects or fishing nets and biting by other fish. A 1994 tag loss study on spaghetti tagged sockeye and coho salmon in the Taku River found negligible tag loss between mark and recapture sites (Milligan et al. 1996). However tag loss increases with migration distance (McFarlane et al. 1990) and tagged fish on the Taku River are recaptured no more than 20 kilometres from the tagging site whereas mark and recapture sites on the Yukon River can be separated by as many as 241 kilometres.

As indicated in the section Pooled Petersen Abundance Estimates on page 11, the actual number of tags applied in this study was reduced by 10% to produce the value *M* that was used in the calculation of abundance estimates. This was done in order to accommodate tag loss and tag-induced mortality. Variability due to tag loss is not reflected in the Petersen standard error (Arnason et al. 1996). However, if less than 10% of the tagged chinook salmon were actually removed from the population, then abundance may have been underestimated. If more than 10% of the tagged chinook salmon were removed from the population, abundance may have been overestimated, although somewhat less so if this is due to mortality than if it is due to tag loss. Bromaghin (1990) noted that

the proportion of chinook salmon suffering tag loss probably varies annually and possibly varies within a single season. Using data obtained from the 1987 mark-recapture study, Bromaghin (1990) also examined the sensitivity of the Petersen abundance estimator to correction factors ranging from 0% to 20%. He found the resulting estimates of abundance to range approximately from 26,000 to 32,000 fish.

A tag loss study in which a portion of the tagged chinook salmon are also given a secondary tag or mark such as a fin hole punch and subsequent recaptures are examined for both marks by trained observers would provide a reliable estimate of tag loss. Adjusting for tag loss insofar as it occurs may remove bias from the Petersen estimate.

Assumption 2. The survival and behaviour of marked and unmarked fish is the same.

If tagged fish had a lesser probability of survival between the fishwheels and the commercial fishery than untagged fish or underwent a change in behaviour as a direct result of tag application, tags could have been removed from the population available for recapture. For example the stress of holding and tagging may have caused mortalities in some fish.

Changes in behaviour could affect vulnerability to recapture, prevent random mixing with untagged fish or be a precursor to death. Fish are known to exhibit abnormal behaviour such as temporary cessation of migration or increased or erratic movement for varying time periods after tagging (Ricker 1975). Chinook salmon in the Yukon River have been observed to be more lethargic after tagging than other species of salmon (Milligan pers. comm. 1997). In the 1982 - 1983 Yukon River chinook salmon mark-recapture program, Milligan et al. (1985) found that erratic post-tagging behaviour and vulnerability of radio-tagged fish to recapture in the upriver commercial fishery were significant. A number of factors identified as potentially influencing the behaviour of the fish radio-tagged in this study were relatively high water and suspended solid levels, confinement, and transmitter application itself.

In 1990 - 1995 small numbers of tagged chinook salmon were recovered downstream of the Yukon River fishwheels (Table 20). Similarly chum salmon tagged at Sheep Rock and White Rock fishwheels in a mark-recapture program identical to the one for chinook salmon have been recovered in the downstream tributary Fishing Branch River (Fig. 1). These chinook and chum salmon could be downstream spawners but it is also possible that much of this downstream migration was a result of holding and tagging stress.

It is believed that there is a direct correlation between the length of time that a chinook salmon is held and the length of time it takes to resume its migration after tagging. Since sampling in the Yukon River mark-recapture program takes place only twice daily, some captured chinook salmon remain in holding pens for over 12 hours. Release location could also influence post-tagging migration behaviour. A significant decrease in erratic behaviour was observed in the Taku River system when radio-tagged chinook salmon were released into slack water (Pat Milligan, pers. comm.). Velocity is lower at the Yukon River tagging site than at the Taku River tagging site but this still could be a factor. Unfortunately, on the Yukon River, release of chinook into the calm water between the fishwheels and the bank results in an increase in the probability of recapture, which also is believed to increase stress.

The behavioural and physiological effects of tagging stress on Yukon River chinook salmon have not been adequately investigated. A study in which chinook salmon are subjected to different regimes of holding and tagging stress and then confined in pens for observation and possibly blood chemistry sampling over time could provide much needed insight into the effects of tagging.

Tag-induced mortality or changes in behaviour causing decreased susceptibility to capture would have the same effect on the Petersen estimate as unchecked tag loss (Assumption 1). Chinook salmon that resumed normal migratory movement after some delay would not have biased a pooled Petersen estimate since the relative time of marking and recapture events is not relevant. However migration delays due to tagging would have affected estimates based on stratification with respect to time. The latter is discussed in the section The Stratified Population Estimate on page 53.

Assumption 3. Either or both the captures for marking and the recaptures were random; that is all fish had the same probability of being marked and/ or all fish tagged and untagged had the same probability of being captured in the recovery sample, or there was uniform mixing of tagged and untagged fish.

It is known that the sex and length composition of chinook salmon captured in the Yukon River fishwheels between 1990 - 1995 is different from that of chinook salmon captured in the commercial fishery, indicating that vulnerability to these two fisheries is a function of biological characteristics and neither equal nor random for marked and unmarked fish. As discussed in Adjustments for Capture Selectivity on page 35, in all years 1990 - 1995 of the Yukon River chinook salmon program, capture for marking favoured smaller fish and recapture favoured larger ones (Table 30). In 1990, 1992 - 1993 and 1995, capture for marking favoured male chinook salmon relative to recapture in the commercial fishery which favoured female chinook salmon (Table 29).

This capture selectivity for length and sex are likely related (since large chinook salmon appear to comprise a greater proportion of the total female catch than of the total male catch (Length Commposition on page 32)) and together or separately should have positively biased the Petersen estimate, in this case because the probability of recapture of marked individuals was less than for unmarked individuals (Bromaghin 1990). For this reason abundance estimates were calculated separately for sex and length categories in 1995. From 1990 - 1994, sex and length composition data were not available for the commercial fishery catch and the pooled Petersen abundance estimates for these years do not take in to account differing probabilities of capture and recapture.

There are a number of reasons why the capture and recapture techniques in the DFO mark-recapture program may have selected chinook salmon differentially. Fish were captured for marking in fishwheels located at two sites within seven kilometres of each other along the right bank of the Yukon River, while recapture occured primarily in large mesh gillnets (which target large chinook) by up to 19 commercial fishers in a given day at various locations throughout a 241 kilometre stretch of river. Tagging occurred daily but recapture was possible only during fishery openings.

Clearly neither the marking nor the recapture event was truly random. However, the degree to which this assumption is violated and more specifically, the robustness of the estimator, are

unknown (Bromaghin 1990). Arnason et al. (1996) note that the Petersen estimate is sensitive to violation of the assumption that all individuals belonging to a stratum have equal probability of recapture and that this violation can result in over- or underestimation of the abundance. Seber (1982) indicated that bias from this violation can be reduced by having differing methods of capture and recapture. However in this case capture and recapture probabilities must be independent of one another otherwise serious bias is introduced (Bromaghin 1990). It is possible to speculate on the factors that may have influenced the sampling but it is not generally possible to test for their effects using only sampling data:

1) As already discussed in relation to Assumption 1, if the catchability of chinook salmon changes after tagging due to behavioural alteration induced by tagging, the recapture sample will not be random;

2) Tagging may have caused contagious movement and catching such that chinook salmon that were tagged and released together failed to disperse randomly before reaching recapture sites and were either uniformly available or uniformly unavailable to recapture fisheries (Dempson & Stansbury 1991), resulting in under- and overestimated abundances respectively. The amount of mixing between tagged and untagged fish may vary between fishing sites close to and far from the tagging site. However, compared to most riverine mark-recapture studies of adult salmon the distances between tagging and recapture sites are very large.

3) The probability of recapture can vary geographically over the region occupied by the population (Darroch 1961) and the effort expended in catching chinook salmon was not uniform throughout the Yukon River. For example different components of the group of tagged chinook salmon could have differential catchability in certain locations or situations. Proximity to a specific river bank or tributary, or depth, temperature and other hydrological factors could increase the catchability of a given stock. The recovery effort is not completely random since fishers favour and exploit specific areas.

4) For the marking event to capture a random sample, a constant proportion of fish must be tagged each day. For example in a Fraser River, B.C. pink salmon study Schwarz and Taylor (1996) suggested that tagged to untagged ratios that were higher in the beginning of the study than at the end could be due in part to changing tagging rates over time (as well as change in movement over time and different recapture rates as a function of time and space). It is believed that on that both the age and sex composition and volume of Yukon River fishwheel catches are influenced by water level. Further studies should investigate the relationship between river condition data such as temperature and rate of flow and fishwheel catches.

Assumption 4. The population was closed; that is there was only a negligible amount of loss from or recruitment to the catchable abundance during the time the recoveries were being made.

As noted by Bromaghin (1990) this assumption is seriously violated because i) fish are continuously entering the population from the border, ii) fish are continuously leaving the population to migrate upriver of the commercial fishery. Failure of fish to resume upstream migration after tagging would also violate this assumption. Bromaghin (1990) was unsure whether the statistical properties of the Petersen estimator are compromised when it is used for estimating abundance in a

riverine system where fish are continually migrating in one direction. He suggested that a time stratification may help.

If a population is closed then its size is constant and the Petersen formula calculates one estimate of both the abundance at the time of tagging and at the time of recapture (Schwarz and Taylor under review). If marked and unmarked fish leave the system at the same rate and no fish enter then the Petersen produces a consistent (unbiased in large sample experiments) estimate of abundance at the time of tagging, N (Bromaghin 1990). If no fish leave the system but new fish enter, the Petersen estimate produces a valid estimate of abundance at the time of recapture, $N + B$ (the B is for births or recruitment) (Arnason et al. 1996; Bromaghin 1990). If tagged and untagged fish leave the system, even at the same rate and new fish enter (this is the case for the DFO program), the Petersen estimate over-estimates the abundance at the time of both tagging (N) and recapture ($N + B$) events (positively biased estimator) (Arnason et al. 1996; Bromaghin 1990). Schwarz and Taylor (1996) simply call the Petersen an inconsistent estimator in the case where both loss and recruitment occur. However, Arnason et al. (1996) have indicated that the Petersen estimate is consistent in this case for $N+B/\Pi$ where Π is the proportion surviving from the first to the second sample.

The tag recaptures used in the chinook salmon abundance estimates were from commercial catches below the Stewart River. There are no tributaries between the tagging site and the Stewart River which could account for major emigration from the population. As previously discussed, it is likely that tag-induced deaths which occurred were accounted for in the 10% reduction adjustment in the number of tags applied (M). The effect of differential catchability of certain sex or length categories between the fishwheels and the commercial fishery is the same as loss of these individuals from the population after tagging. This bias was addressed in 1995 by calculating separate abundance estimates for sex and length categories.

<u>Assumption 5 Failure to see or report tags has the same effect as tag loss and results in an overestimation of abundance.</u>

The bright orange tags used in the Yukon River mark-recapture program are easily recognised. Fishers have been reporting catches and providing tag recaptures to DFO yearly since 1985. Nonetheless, incomplete or mis-reporting is undoubtedly a source of error. The extent to which this happens is unknown. Tags may be lost because large numbers of fish are handled by fishers. The potential exists for fishers to provide mistakable records of catch statistics, perhaps in part because the intensity of the commercial fishery leaves little time for record-keeping tasks. It is also possible that some commercial fishery catches and/ or tag recoveries are reported as aboriginal catches by Yukon River commercial fishers who also hold aboriginal licences. Once the commercial fishery closes these dual licence holders are able to change their licence display sign and continue fishing without a break. If this type of mis-reporting occurred, commercial catch and recapture information would be excluded from population abundance calculations.

Because recaptures in the Yukon River program take place over 241 kilometres of river, it is impossible to monitor all reporting directly. DFO is currently formulating clearer and more readily enforceable guidelines for commercial fishery catch reporting and tag returns. DFO is also revising catch report forms in order to increase the ease and accuracy of reporting. Increased

understanding of the mark-recapture program and increased tag rewards would likely have a positive effect on the accuracy of tag return information.

THE STRATIFIED POPULATION ESTIMATE

While the problems of bias associated with non-random mixing and variable catchability are best tackled by a sampling strategy designed to minimise these effects (Arnason and Baniuk 1978), in most programs, including this one, it must also be addressed in subsequent analysis. One way in which to reduce error resulting from capture bias over time is to use a generalisation of the Petersen estimate in which marking and recapture events are allocated into distinct temporal strata for which separate abundance estimates are calculated and can then be summed to obtain total abundance. This technique of stratification has been developed by Schaefer (1951), Chapman and Junge (1956 in Ricker 1975) Darroch (1961) & many others subsequently. Another advantage of this technique is that it allows abundance estimates to be determined for each strata used. Schaefer and Darroch abundance estimates of Yukon River chinook salmon were calculated in 1995 using mark-recapture data stratified into weekly time periods. These estimates are based on the same assumptions that apply to the Petersen with some simple modifications that are explained in the following sections.

In the calculation of stratified estimates, early and late tagging and recapture statistical weeks were selectively pooled in order to reduce the number of data matrix cells with low or zero values. One advantage of pooling data is that it reduces the number of parameters that need to be estimated, generally providing a more precise estimate of total abundance (Arnason et al. 1996). Arnason et al. (1996) suggest that optimal pooling is achieved by pooling strata that contain data that are as homogeneous as possible with respect to capture, migration, and recapture. Since only early or late strata were pooled, it is probable that this goal of homogeneity was achieved as much as possible. Arnason et al. (1996) note that some lack of homogeneity (leading to increased bias) can be traded off by the increased precision that comes from reducing the number of estimated parameters.

One potential source of variability in the 1995 abundance estimates that were calculated separately for separate sexes and length classes is the sampling error associated with estimation of strata composition for commercial catches (Bromaghin 1990). While the strata for specific classes of chinook salmon captured in fishwheels is known without error, the commercial fishery catch is stratified based on a commercial sample. In 1995, 1,352 chinook salmon out of a total commercial catch (associated with tags) of 11,044 (12.2%) were sampled. Sampling was done according to convenience. Future programs should consider whether the level and randomness of sampling is sufficient to provide the desired accuracy.

As mentioned previously, chinook salmon that experience a change in probability of recapture (for example migratory delay) as a result of tagging may more seriously affect a stratified estimator than the pooled Petersen. In a stratified estimate, the assumption that all fish had the same probability of capture and/or recapture can be violated many times. This is because the proportion of individuals marked may vary between strata and individuals from different initial strata may have different chances of moving to and/ or being sampled in final strata (Arnason et al. 1996). Chinook

salmon that have altered probabilities of recapture as a result of tagging will cause differences in overall capture rates between marked and unmarked individuals in numerous strata. Error in multiple strata will be compounded in the final estimate, resulting in a seriously biased estimate. This problem would be more critical in the Schaefer estimate than in the Darroch because the former, like the Petersen, is not robust in its ability to tolerate violations to the assumption of constant probabilities of capture over all strata.

SCHAEFER ESTIMATE FOR STRATIFIED POPULATIONS, 1995

The Schaefer technique for stratified populations calculates an estimate of abundance using ratio and expectation arguments. The assumptions of the Schaefer estimate are the same as those for the Petersen estimate. Like the Petersen estimate, the Schaefer estimate is biased unless capture probabilities p^c_i are equal across all initial strata i, and/ or the recapture probabilities p^r_j are the same across all final strata j (Arnason et al. 1996). If this assumption is upheld then the pooled Petersen will use the data more efficiently (Arnason et al. 1996). However, given that in the Yukon River program neither marking nor recapture samples are random, the Schaefer has some advantages which may allow it to better accommodate this violation than does the Petersen estimate: 1) where successive tagging strata maintain separate identities and can be treated as separate populations the Schaefer will frequently give a better estimate than the Petersen; 2) although usually it is desirable to have sustained distinctness between fish tagged in successive strata (either complete separation or complete random mixing at tagging or recapture) rather than some intermingling between strata, the Schaefer does well in the latter situation; 3) the Schaefer provides estimates of the population present in successive strata, both at the point of tagging and at the point of recapture (Ricker 1975). While the Schaefer estimate is computationally simple, it is disadvantageous in that it does not allow the calculation of confidence limits for the final population estimate.

There are two conditions which, if satisfied, indicate that either a Petersen or Schaefer estimate may be appropriate. Firstly, the number of tagged fish recaptured over time should be consistent with the number of tagged fish released, suggesting a constant probability of capture based on Seber's (1982) test statistic (Dempson & Stansbury 1991). Secondly, the number of recaptures (R) and captures (C) should be homogenous, that is the ratio of tagged fish captured over time should be proportional to the number of unmarked fish at the time of recapture: if so then random mixing of tagged and untagged fish can be assumed (Dempson & Stansbury 1991). Ratios of tags applied to tags recovered as shown in the Schaefer data matrices (Table 3 – Table 9) are consistent within matrices for mid-run statistical week strata. In most pooled statistical weeks of application and recapture at the beginning and at the end of the run, ratios of tags applied to tags recovered were greater than at mid-run. Ratios of captures (C) to recaptures (R) in the same data matrices decline over the progression of the recapture strata in time. This is similar to what was found in a pink salmon study in the Fraser River, B.C. where the Pacific Salmon Commission (in Schwarz and Taylor 1996) noted that higher tagged to untagged ratios in the early segment of dead recoveries than in later segments could have been caused by differences in tagging rates over time, differences in movement over time and differences in the recapture rates in time and space.

Ratios in mid-run statistical weeks were lower in the female estimate than in the male estimate and decreased with increasing length in the case of the estimates by length. A weekly

tags applied to tags recovered ratio low of 2.56 (39.1%) and high of 3.80 (26.3%) were observed for the female chinook salmon estimate (Table 5), compared to a corresponding low of 5.69 (17.6%) and high of 6.80 (14.7%) for the male chinook salmon estimate (Table 4). The weekly tags applied to tags recovered ratio in mid-run statistical weeks was highest in the < 800 mm fork length estimate, ranging from 7.03 (14.2%) to 8.88 (11.3%) (Table 6) and lowest in the > 999 mm fork length estimate, ranging from 1.67 (59.9%) to 2.04 (49%) (Table 9). These tag exploitation rates correspond with significant chi-square tests (Table 29 and Table 30) and length histograms (Fig. 20 - Fig. 22) in indicating that the commercial fishery captures female and large chinook salmon in greater proportions than it does male and smaller chinook salmon.

DARROCH ESTIMATE FOR STRATIFIED POPULATIONS, 1995

The Darroch method for stratified tagging and recapture uses maximum likelihood to estimate abundance (Darroch 1961). The Darroch method reduces the bias resultant from varying probabilities of capture over the course of an experiment by allowing this probability to vary between strata and thereby producing a better estimate than either the Petersen or the Schaefer in the case where probabilities of capture are not constant (Arnason et al. 1996). The underlying assumption is that all marked animals released in a given first-sample stratum have the same probability distribution of movement to the second-sample strata, and that all animals, marked and unmarked, in a given second sample stratum have the same probability of capture. Darroch (1961) indicates that these assumptions are sufficient when $s \geq t$, as is the case for all our data matrices (Table 10 – Table 16). If the assumption of independent movement and catching of the marked animals is dropped, the estimates are still consistent and the formulae for their variances undergo only minor changes (Darroch 1961). Another advantage of the Darroch estimate is that its precision can be quantified by coefficients of variation and confidence intervals (Schwarz & Arnason 1990).

With the exception of the estimate for female chinook salmon, all 1995 Darroch estimate data matrices had $s > t$ (Table 10 – Table 16). Where $s > t$, the Darroch technique estimates the final stratum (abundance) size (Arnason et al. 1996). The data matrix for 1995 female chinook salmon had $s = t$ (Table 12). In this case, the Darroch technique estimates both the initial and final stratum (abundance) sizes (Arnason et al. 1996). In the case where $s < t$ only the initial stratum sizes can be estimated by the Darroch technique.

Darroch estimate tagging and recovery data matrices were only slightly different from those used to calculate the Schaefer estimate. As in the Schaefer data matrices, ratios of tags applied to tags recovered were consistent within matrices for mid-run statistical week strata. In most pooled statistical weeks of application and recapture at the beginning and at the end of the run, ratios of tags applied to tags recovered were greater than at mid-run. Mid-run weekly tags applied to tags recovered ratios were lower for the female estimate and decreased with increasing length in the case of the estimates by length. A weekly tags applied to tags recovered ratio low of 2.67 (37.5%) and high of 3.81 (26.2%) were observed for the female chinook salmon estimate (Table 12), compared to a corresponding low of 5.77 (17.3%) and high of 6.80 (14.7%) for the male chinook salmon estimate (Table 11). The weekly tags applied to tags recovered ratio was highest in the < 800 mm fork length estimate, ranging from 7.03 (14.2%) to 8.86 (11.3%) (Table 13) and lowest in the > 999 mm fork length estimate, at 2.05 (48.8%) for statistical week 30 (Table 16).

As in the Schaefer estimates, these tag exploitation rates correspond with significant chi-square tests (Table 29 and Table 30) and length histograms (Fig. 20 - Fig. 22) in indicating that the commercial fishery captures female and large chinook salmon in greater proportions than it does male and smaller chinook salmon.

ABUNDANCE ESTIMATES BY SEX AND LENGTH

The 1995 estimates that are within the confidence limits of the combined pooled Petersen are the pooled Petersen by sex, Schaefer by length, combined Darroch, lower confidence limit of the combined Darroch and the Darroch by sex (Table 33). All the 1995 estimates are within 15% of the combined pooled Petersen estimate (Table 34). All the abundance estimates calculated by the Schaefer and Darroch estimators are slightly higher than the pooled Petersen estimates. Combined Schaefer and Darroch estimates are 10.2% and 6.4% higher respectively than the combined Petersen estimate. The Schaefer and Darroch estimates by sex were 9.7% and 2.6% higher respectively than the Petersen estimate by sex, and by length were 9.5% and 6.6% higher respectively than the Petersen estimate by length. The Darroch by sex was 6.5% lower than the Schaefer by sex and the Darroch by length was 2.7% lower than the Schaefer by length. Whether or not the pooled Petersen is negatively biased due to factors for which temporally stratified estimators can correct is unknown.

For Petersen, Schaefer and Darroch estimates, separate calculations by sex resulted in similarly higher estimates (0.3% - 3.7%) and separate calculations by length resulted in similarly lower estimates (14.6% - 15.5%) than the combined estimate of the same type (Table 34). In Section 4.1 it was noted that violation of the assumption of equal probability of capture and recapture for marked and unmarked fish may have positively biased the Petersen estimates. Calculating separate estimates for separate sex and length strata of chinook salmon should have reduced the effect of this violation. Thus the lower estimates in calculations by length were expected. That the estimates by sex are slightly higher than combined estimates of the same type may suggest that capture selectivity by length has the greater effect on the abundance estimate.

The major problems with calculating separate estimates by sex and length were the resultant small sample sizes and relatively large differences between high and low confidence limits and the estimate itself. Total sample sizes for tags recovered and tags applied were as low as 41 and 98 respectively (Schaefer and Darroch) for estimates of chinook salmon > 999 mm in fork length (Table 9, Table 16 and Table 32). Confidence limits for estimates of separate sexes were 14.3% and 12.5% (upper and lower male) and 15.5% and 13.4% (upper and lower female) of the abundance estimate itself for the Petersen (Table 32) and 16.2% (upper and lower male) and 18.6% (upper and lower female) for the Darroch estimate (Table 42). Confidence limits for estimates by length ranged from 15.7% (lower 800 - 899 mm) to 34.5% (upper > 999 mm) for the Petersen estimate (Table 32) and 17.3% (upper and lower 800 - 899 mm) to 23.7% (upper and lower > 999 mm) for the Darroch (Table 42 and Table 43). Confidence limits were not available for Schaefer estimates, nor were they available for weekly or summed Darroch estimates. The U.S. Darroch model does calculate confidence limits for strata estimates and may be useful for in-season estimates. Weekly confidence intervals would allow a more thorough assessment of error in the Darroch estimate.

A mark-recapture estimate is generally considered to be reliable if its confidence limits are within ±10% and its coefficient of variation is less than 5% (Roff 1973 cited in Dempson & Stansbury 1991). In comparison, the International Pacific Salmon Fisheries Commission considers a 95% confidence interval of 20% of the estimated population size to be good and an interval of 40% to be average (Cousens et al. 1982 cited in Dempson and Stansbury 1991). Almost all of the confidence limits for abundance estimates of individual sex and length strata were between 10% and 20%. Calculating separate estimates for different sex and length groups (particularly the latter) does seem to provide a more accurate estimate. It is likely that addressing biological and sampling strategy problems previously discussed would increase the confidence and precision of all the estimators to a greater degree than changes in the estimate calculations themselves.

ESCAPEMENT INDICES

The lack of a significant relationship between yearly mark-recapture results and escapement index counts is not surpising given the limited number of data points. A more extensive time series could reveal a significant relationship. Also, enumerator experience and bias, weather and water conditions, spawner density, as well as survey timing can introduce variability into index counts. The Whitehorse Rapids Fishway count, particularly in 1994, may have been an over-estimate of escapement since some hatchery fish were counted more than once. Also, mobile survey methodology varied; for example in 1990, a fixed-wing aircraft was used instead of a helicopter. Increasing the number of indices and surveys per index annually, as well as placing increased emphasis on standardizing methodology, would be of benefit in obtaining more representative spawning escapement counts.

SUMMARY OF RECOMMENDATIONS

The recommendations of this report are:

Existing Program

- Reduced holding time of tagged fish.
- Increase the monetary incentive to fishers for turning in tags along with requisite data.
- Formulate clearer and more readily enforceable guidelines for commercial fishery catch reporting and tag return.

Further study

- Examine whether the capture selectivity of the commercial fishery for female and large chinook salmon is affecting or has the potential to affect the sex ratio, size composition and spawning success of the escapement population.

- Investigate the behavioural and physiological effects of tagging stress on Yukon River chinook salmon. A study in which chinook salmon are subjected to different regimes of holding and tagging stress and then confined in pens for observation and possibly blood chemistry sampling over time could provide much needed insight into the effects of tagging.

- Investigate tag loss on a regular basis.

- Test the other assumptions associated with the mark-recapture program on a regular basis (not necessarily annually).

- Investigate the relationship between river condition data such as temperature and flow velocity and the size, sex ratio and length composition of fishwheel catches in order to relate CPUE to abundance.

ACKNOWLEDGEMENTS

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LITERATURE CITED

Arnason, A.N., C.W. Kirby, C.J. Schwarz, and J.R. Irvine. 1996. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapements and other populations. Can. Tech. Rep. Fish. Aquat. Sci. 0000: vi+36 p.

Arnason, A.N. and L. Baniuk. 1978. POPAN-2: a data maintenance and analysis system for mark-recapture data. Charles Babbage Research Centre, Box 370, St. Pierre, Manitoba, Canada. 269 pp.

Blakely, A.C., M.E. Jarvis, J. McKenzie, K.K. English, and W.B. Griffiths. 2001. Yukon River Drainage Basin Harvest Study 2000. LGL Limited, Sidney, B.C.

Brannian, L.K. 1990. Estimates of total abundance, exploitation rate, and migratory timing of chinook salmon runs in the Yukon River, 1982 - 1986. Alaska Department of Fish and Game, Fishery Research Bulletin No. 90 - 03: 40 p.

Brock, D.H. 1976. Distribution and abundance of chinook (*Oncorhynchus tshawytscha*) and chum (*O.keta*) salmon in the upper Yukon River system in 1974, as determined by a tagging program. Environment Canada, Fish. and Mar. Ser. Tech. Rep. PAC/T-76-3. 56 p.

Bromaghin, J.F. 1990. A comprehensive review of the Yukon River salmon tagging program conducted by the Canadian Department of Fisheries and Oceans. Alaska Department of Fish and Game, Regional Information Report No. 3A90-24: 55 p.

Darroch, J.N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48, 3 and 4: 241- 260.

Dempson, J.B. and D.E. Stansbury. 1991. Using partial counting fences and a two-sample stratified design for mark-recapture estimation of an Atlantic salmon smolt population. N. Am. J. Fish. Manage. 11: 27 - 37.

Mahoney. 1997. Yukon River Basin Domestic Salmon Fishery – Open Channels; Suggested Policy Guidelines and Other Considerations. Yukon Salmon Committee, Whitehorse, Yukon Territory.

Milligan, P.A., M.S. Kelley, and A.J. McGregor. 1996. Review of adult mark-recapture studies of Taku River salmon stocks 1994-1995. Working paper submitted for PSARC review.

Milligan, P.A., W.O. Rublee, D.D. Cornett, and R.A.C. Johnston. 1985. The distribution and abundance of chinook salmon (*Oncorhynchus tshawytscha*) in the upper Yukon River basin as determined by a radio-tagging and spaghetti tagging program: 1982-1983. Dept. of Fish. and Oceans, Can. Tech. Rep. Fish. Aquat. Sci. 1352: 161 p.

Otto, D. K. 1996. Handbook of Yukon River salmon. Department of Fisheries and Oceans, Whitehorse, Yukon Territory.

Otto, D. K. 1996. Attaining a reliable assessment of Yukon River recreational salmon harvest. Yukon Territory Salmon Committee, Whitehorse, Yukon Territory.

Otto, D. K. 1996. Tatchun Creek Chinook Sport Fishery Creel Census, 1996. Department of Fisheries and Oceans, Whitehorse, Yukon.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191: 382 p.

Schaefer, M.B. 1951a. Estimation of the size of animal populations by marking experiments. U.S. Fish Wildl. Serv. Fish Bull. 52: 189-203.

Schaefer, M.B. 1951b. A study of the spawning populations of sockeye salmon in the Harrison River system, with special reference to the problem of enumeration by means of marked members. Int. Pac. Salmon Fish Comm. Bull. 4: 207 p.

Schwarz, C.J. and A.N. Arnason. 1990. Use of tag-recovery information in migration and movement studies. Am. Fish. Soc. Symposium 7: 588 - 603.

Schwarz, C.J. and C.G. Taylor. 1996. The use of the stratified-Petersen estimator in fisheries management with an illustration of estimating the number of pink salmon (*Oncorhynchus gorbuscha*) that return to spawn in the Fraser River. Paper under review by Can. J. Fish. Aquat. Sci.

Seber, G.A.F. 1982. The estimation of animal abundance and related abundance. 2nd edition. Macmillan, New York.

Shaw, W. 1994. Biological Sampling Manual for Salmonids – A Standardized Approach for the Pacific Region. Can. Tech. Rep. Fish. Aquat. Sci. 1998: xiii + 67 p.

Sweitzer, O. 1974. Distribution and abundance of chinook (*Oncorhynchus tshawytscha*) and chum (*Oncorhynchus keta*) salmon in the upper Yukon River system in 1973, as determined by a tagging program. Environment Canada, Fish. and Mar. Ser. Rep. PAC/T-74-20. 24 p.

Wilson, J. 1995. A Summary of Aboriginal Fishery Catches of Salmon in the Yukon/ Northern British Columbia Division, 1994. The Department of Fisheries and Oceans, Yukon/ Northern B.C. Division.

PERSONAL COMMUNICATION

Coukell, G. 1997. Fisher Officer, Conservation and Protection Division, Department of Fisheries and Oceans, Yukon and Northern British Columbia Division.

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Milligan, P.A. 1997. Biologist, Stock Assessment Division. Department of Fisheries and Oceans, Yukon and Northern British Columbia Division.

Smith, S. 1997. Fishery Officer, Conservation and Protection Division, Department of Fisheries and Oceans, Yukon and Northern British Columbia Division.

von Finster, A. 2001. Biologist, Habitat and Enhancement Branch. Fisheries and Oceans, Canada. Yukon/ Transboundary Area.

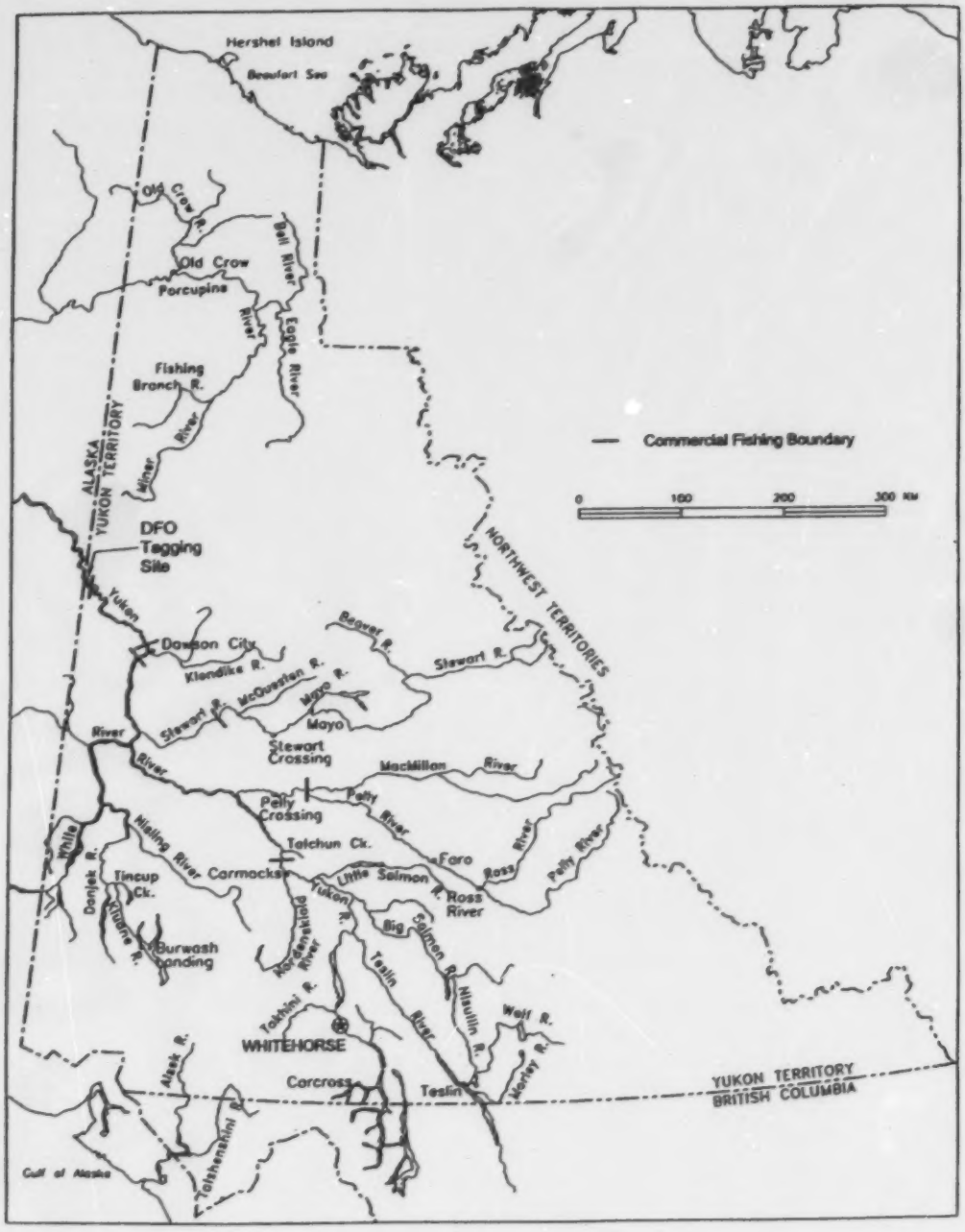


Figure 1. Map of the Yukon Territory showing the tagging site and commercial fishing boundaries.

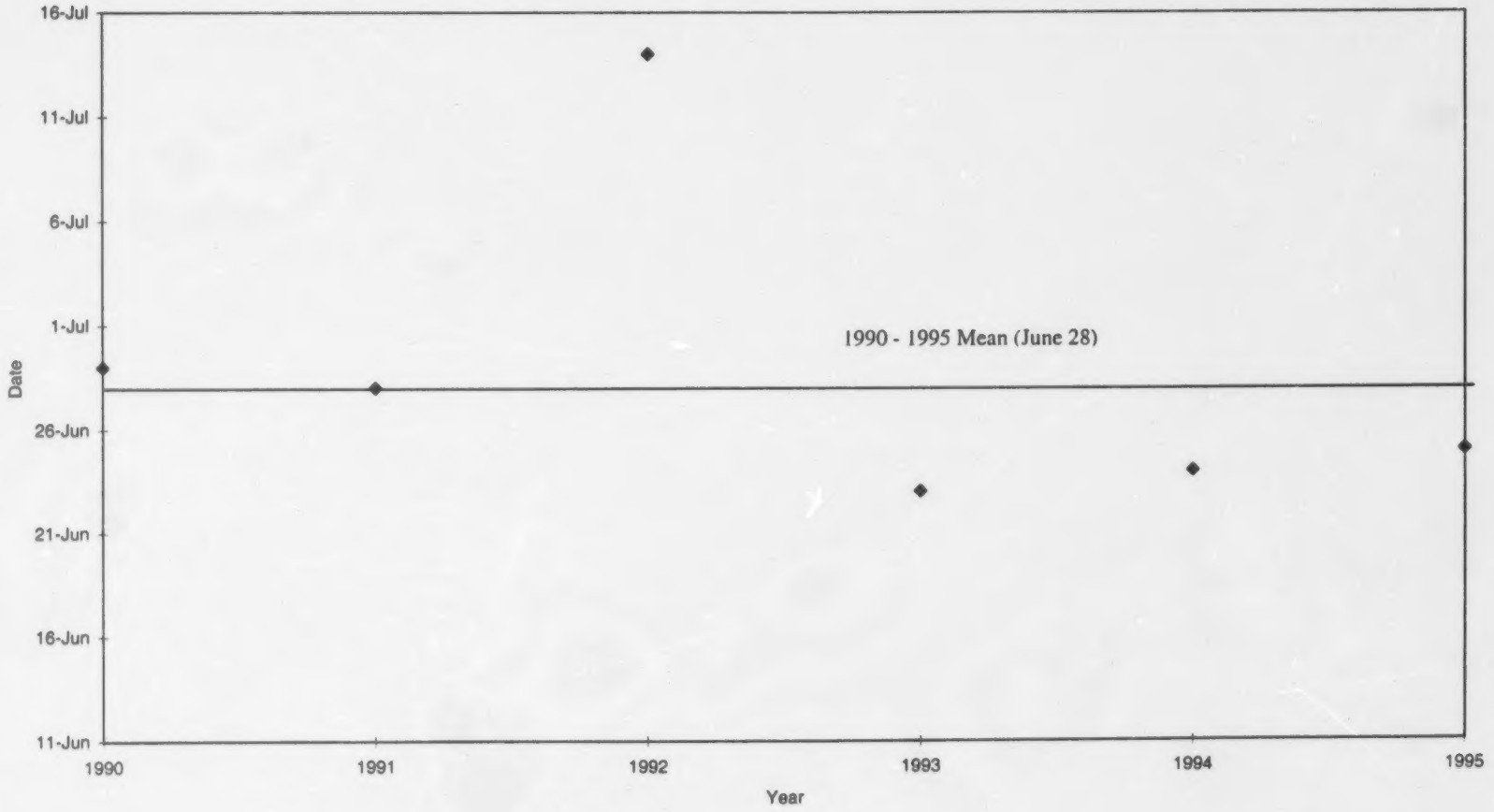


Figure 2. Date of first chinook salmon captured at either Sheep Rock or White Rock fishwheel, Yukon River, 1900 - 1995. Horizontal line shows the 1990 - 1995 mean of June 28.

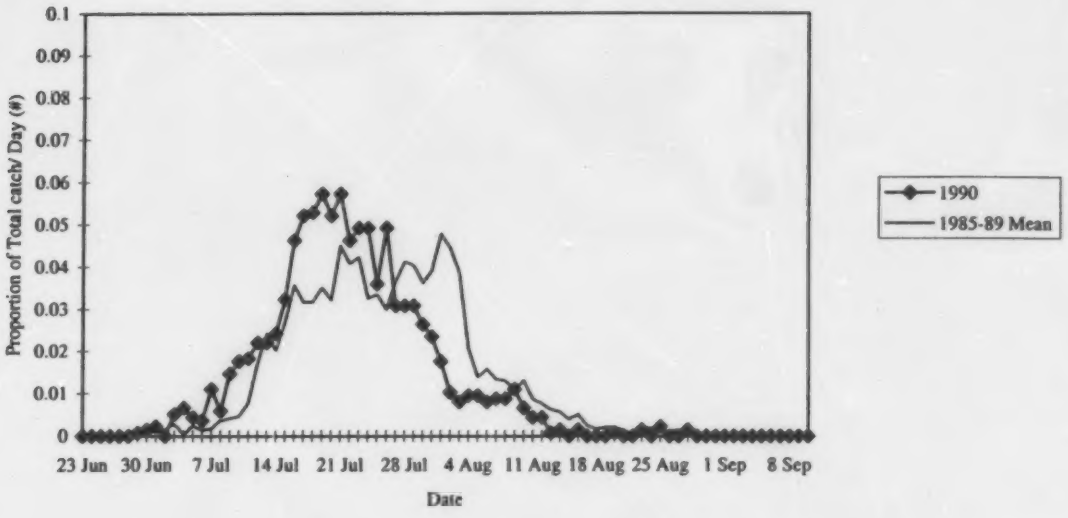


Figure 3. Chinook salmon run timing from combined catches at Sheep Rock and White Rock fishwheels, 1990 and 1985 - 1989 mean. Mean run timing for the six year cycle preceding 1990 is not available because a mark-recapture program was not run in 1984.

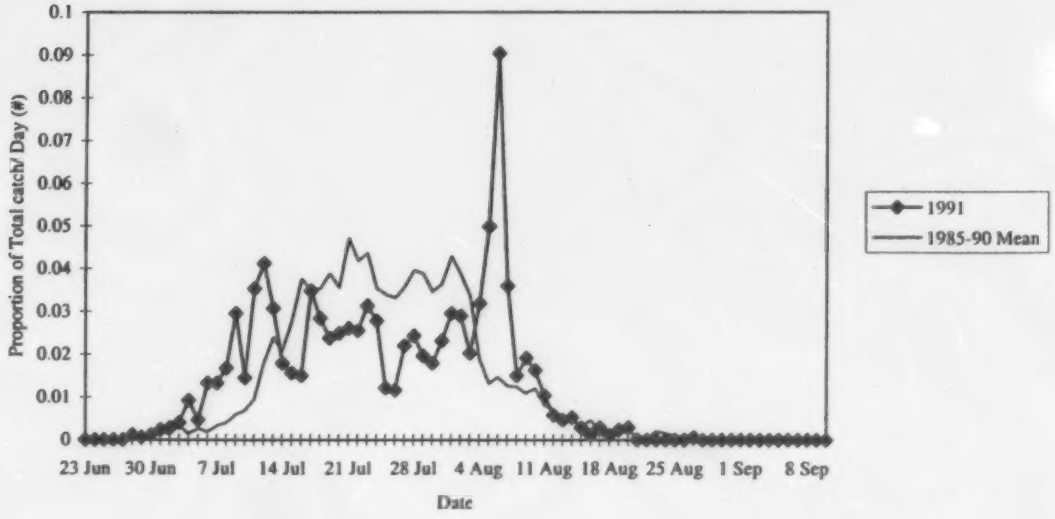


Figure 4. Chinook salmon run timing from combined catches at Sheep Rock and White Rock fishwheels, 1991 and 1985 - 1990 mean.

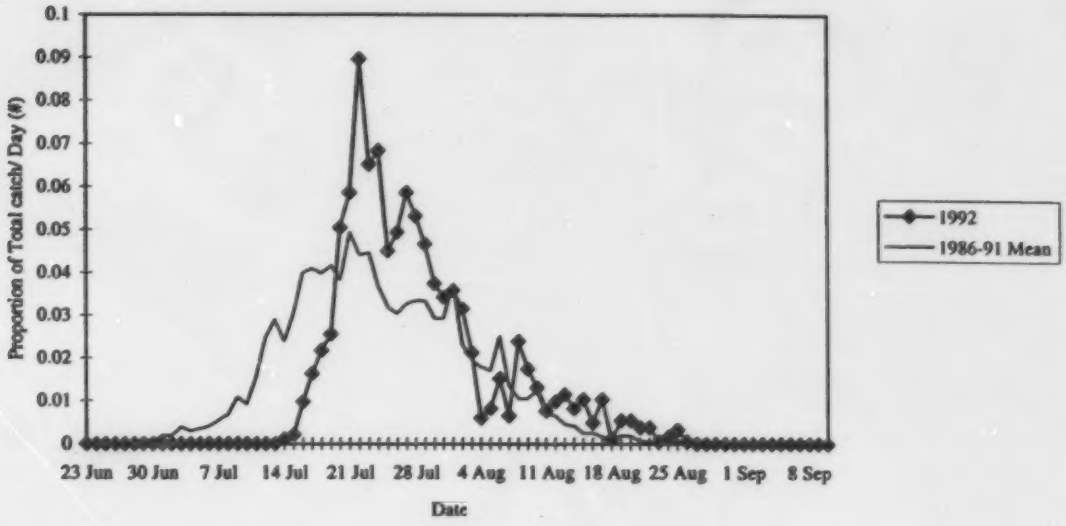


Figure 5. Chinook salmon run timing from combined catches at Sheep Rock and White Rock fishwheels, 1992 and 1986 - 1991 mean.

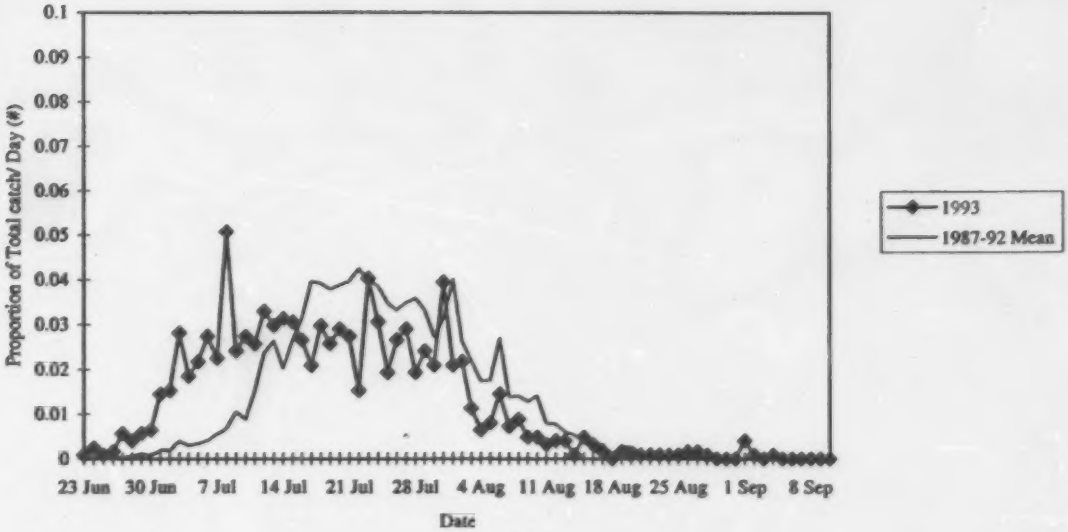


Figure 6. Chinook salmon run timing from combined catches at Sheep Rock and White Rock fishwheels, 1993 and 1987 - 1992 mean.

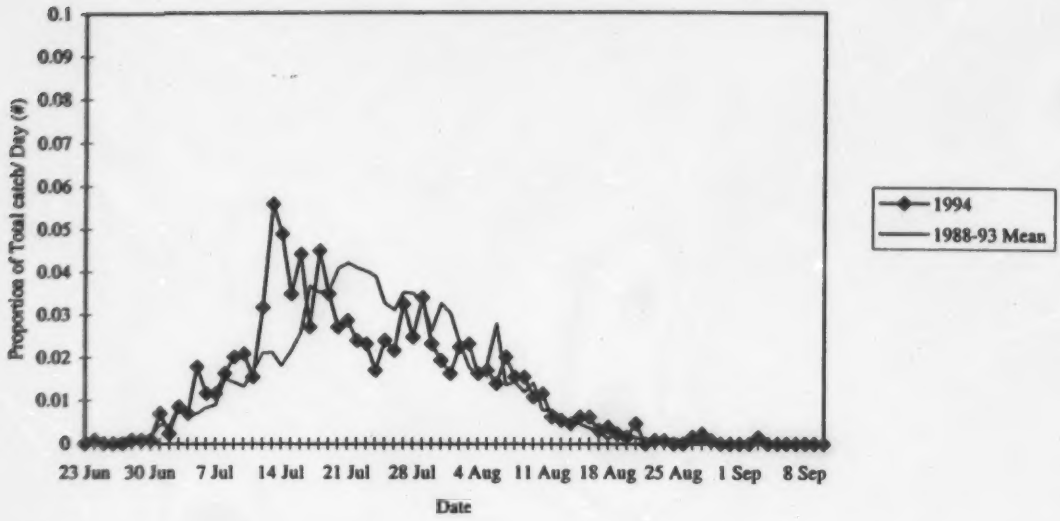


Figure 7. Chinook salmon run timing from combined catches at Sheep Rock and White Rock fishwheels, 1994 and 1988 - 1993 mean.

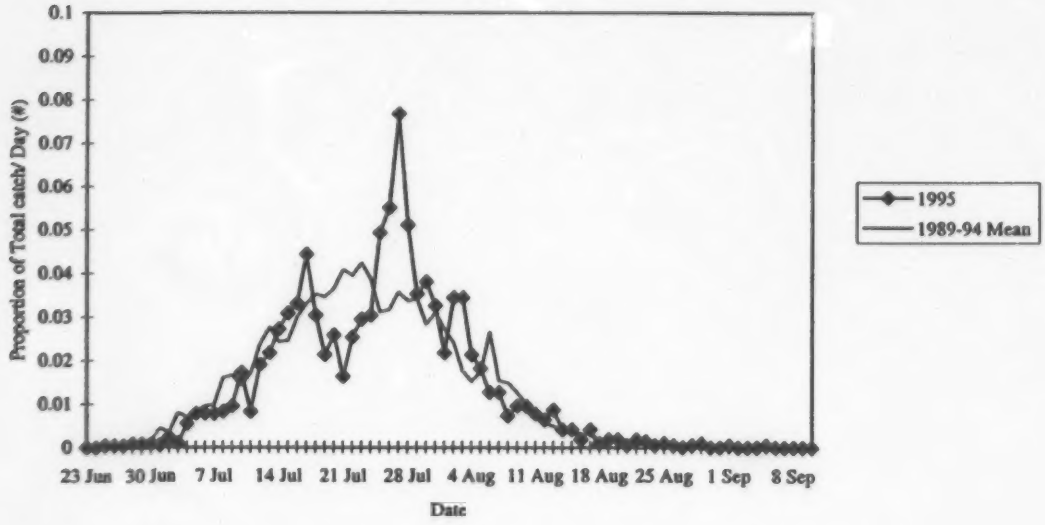


Figure 8. Chinook salmon run timing from combined catches at Sheep Rock and White Rock fishwheels, 1995 and 1989 -1994 mean.

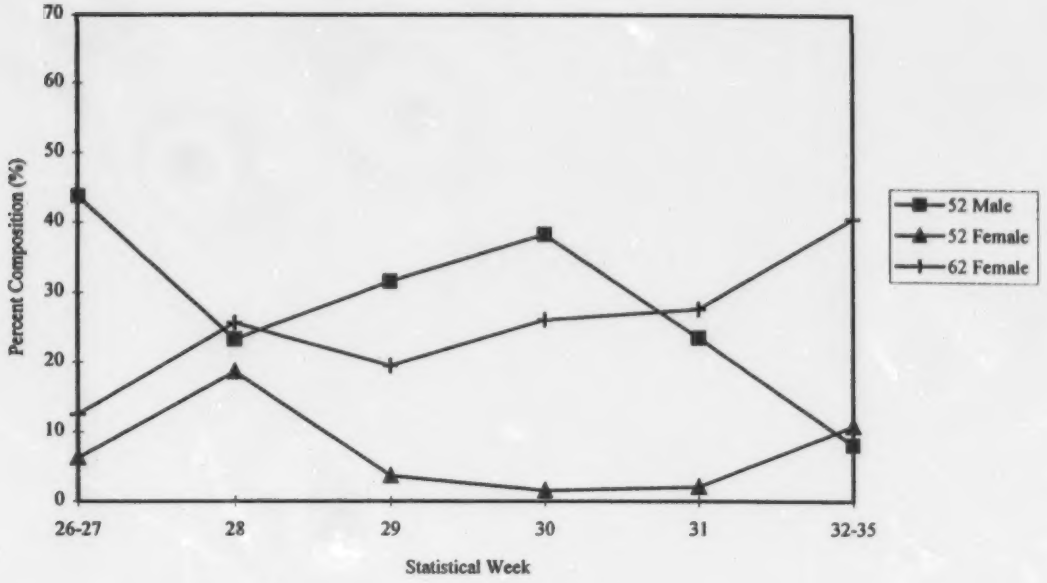


Figure 9. Percent composition of total Sheep Rock and White Rock fishwheel catch in 1990 for sex - age classes showing trends in capture frequency.

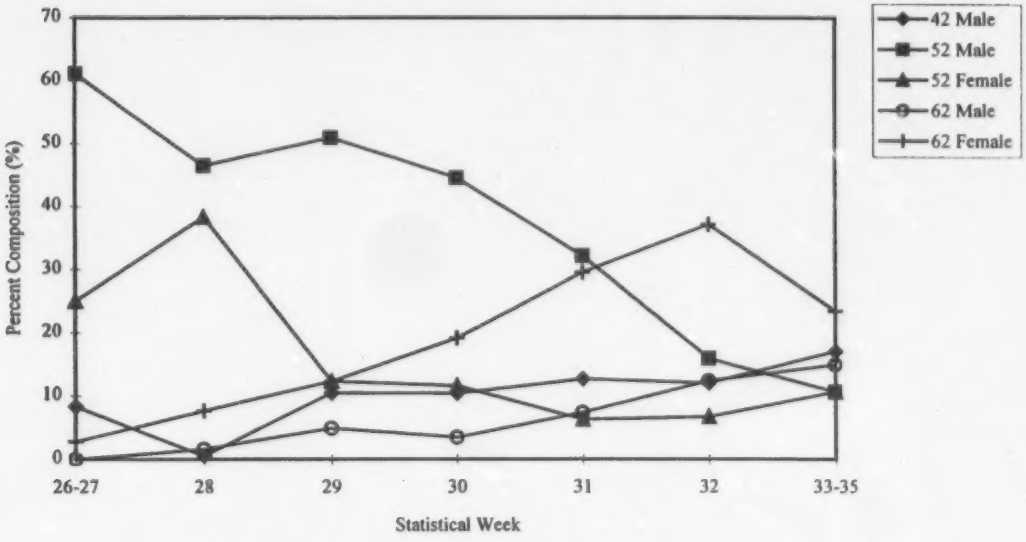


Figure10. Percent composition of total Sheep Rock and White Rock fishwheel catch in 1991 for sex-age classes showing trends in capture frequency.

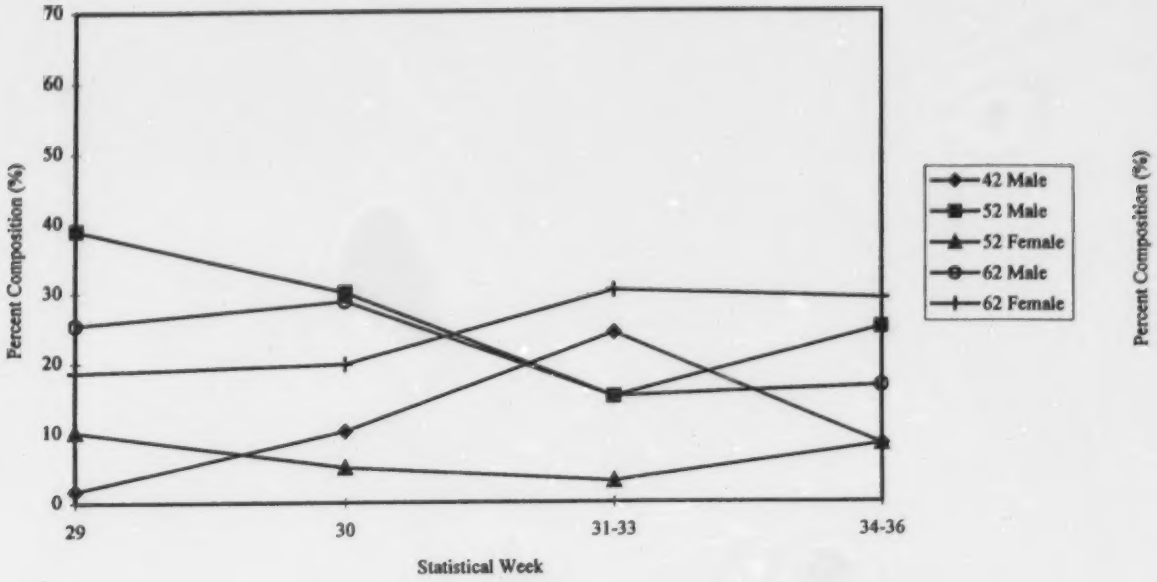


Figure 11. Percent composition of total Sheep Rock and White Rock fishwheel catch in 1992 for sex - age classes showing trends in capture frequency.

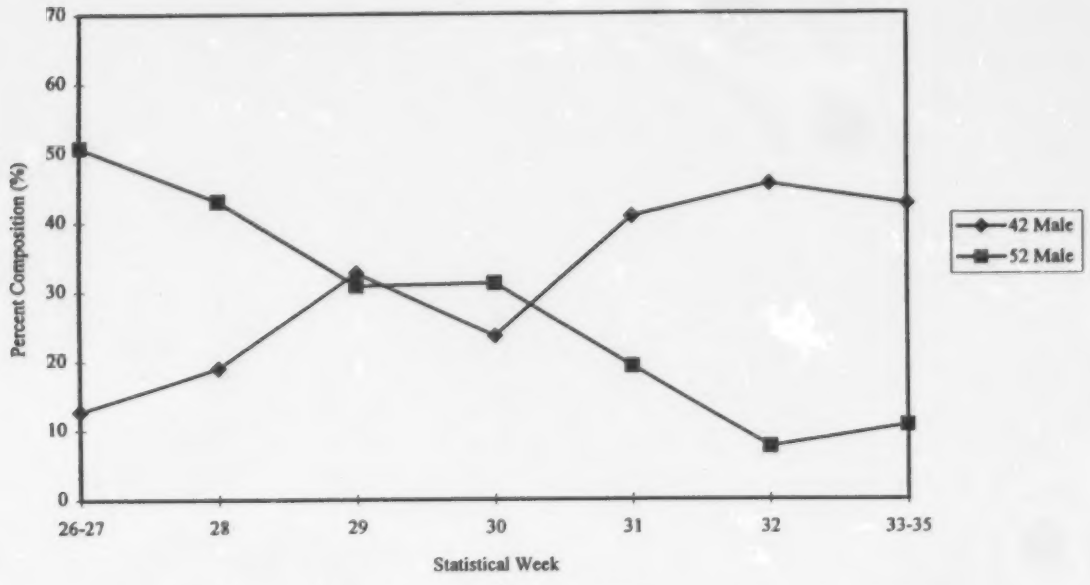


Figure 12. Percent composition of total Sheep Rock and White Rock fishwheel catch in 1993 for sex - age classes showing trends in capture frequency.

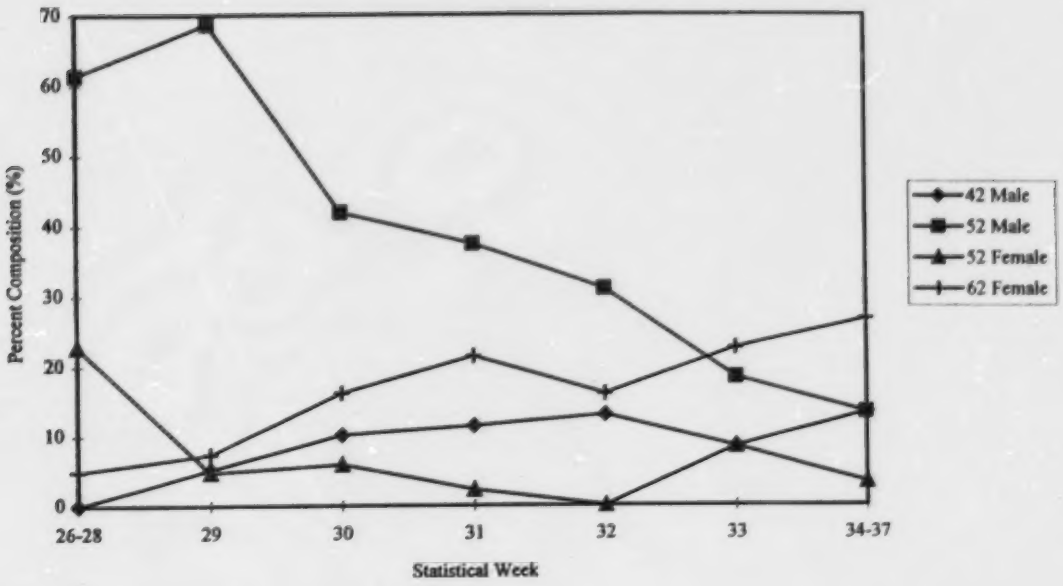


Figure 13. Percent composition of total Sheep Rock and White Rock fishwheel catch in 1994 for sex - age classes showing trends in capture frequency.

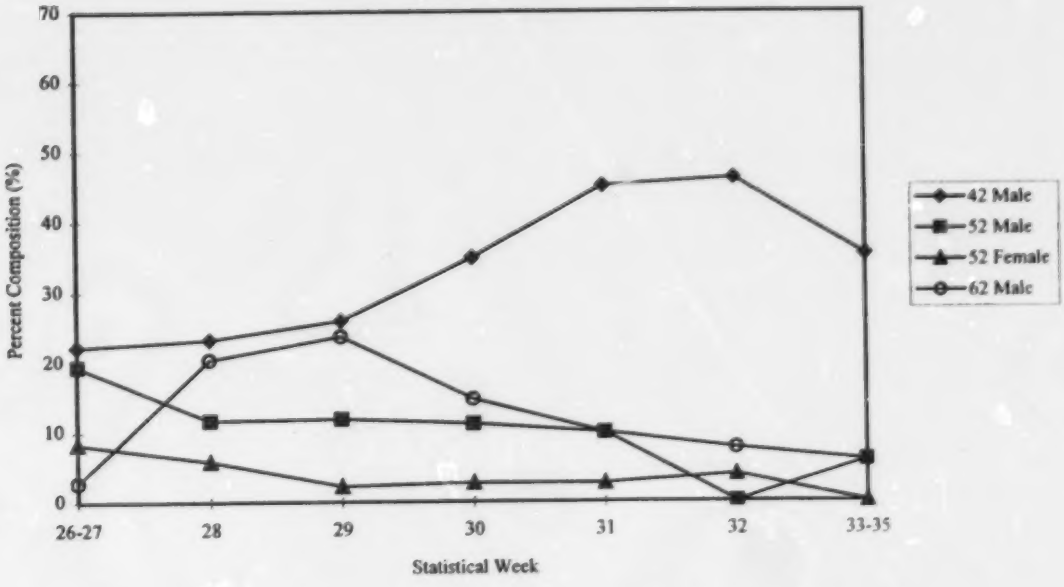
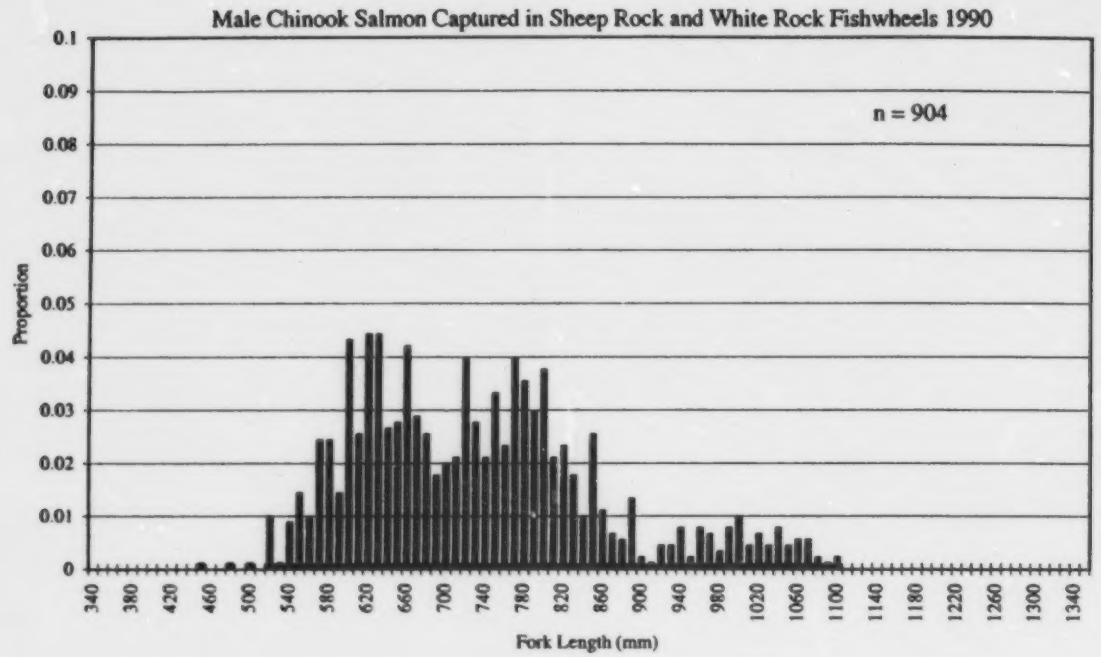


Figure 14. Percent composition of total Sheep Rock and White Rock fishwheel catch in 1995 for sex - age classes showing trends in capture frequency.



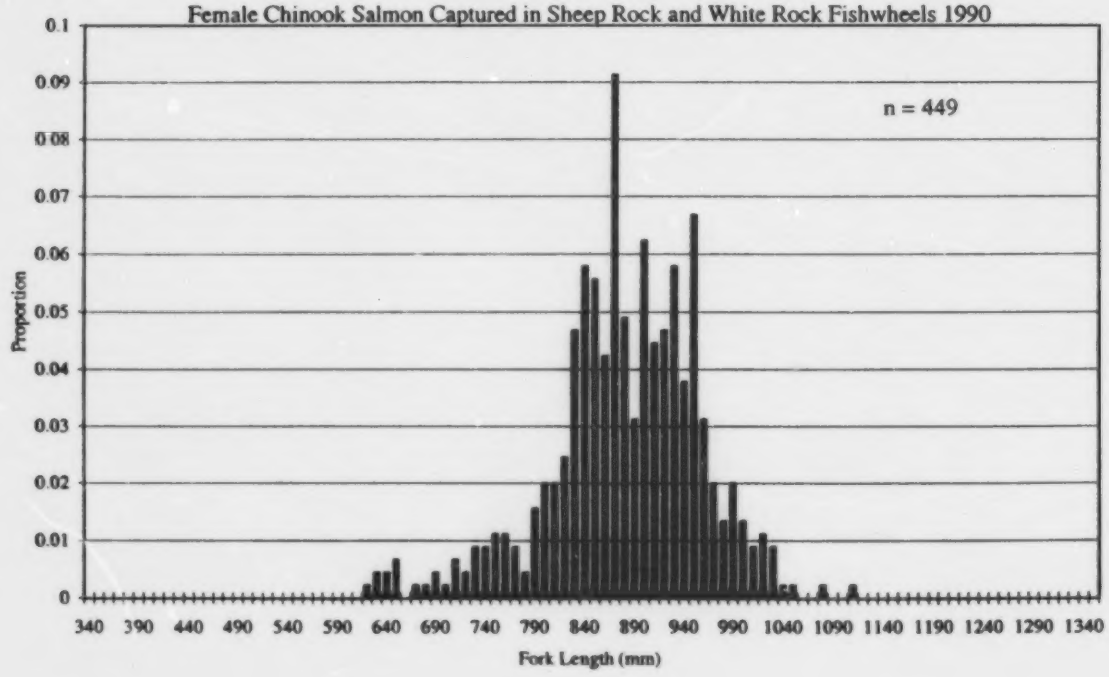
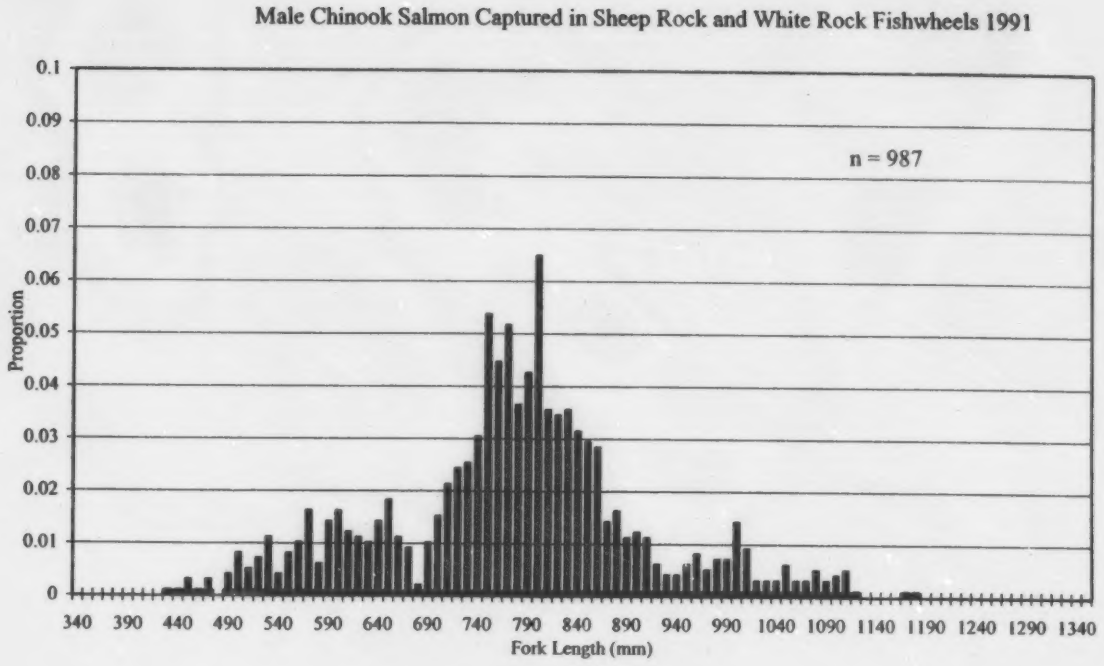


Figure 15. Length frequency of combined Sheep Rock and White Rock fishwheel chinook salmon catches, 1990.



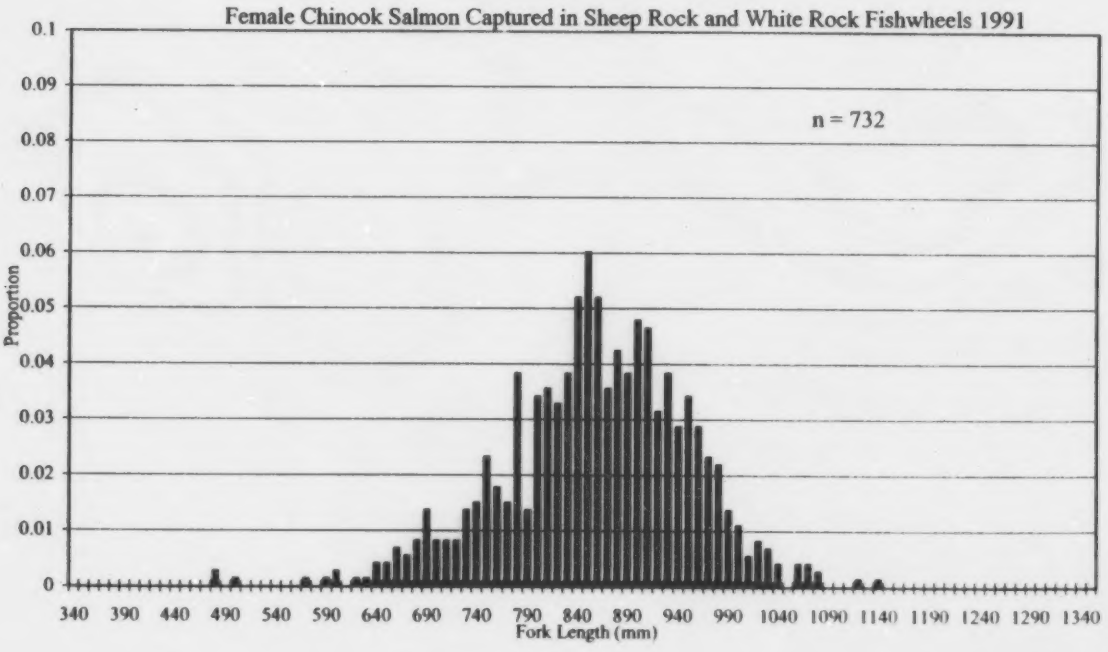


Figure 16. Length frequency of combined Sheep Rock and White Rock fishwheel chinook salmon catches, 1991.

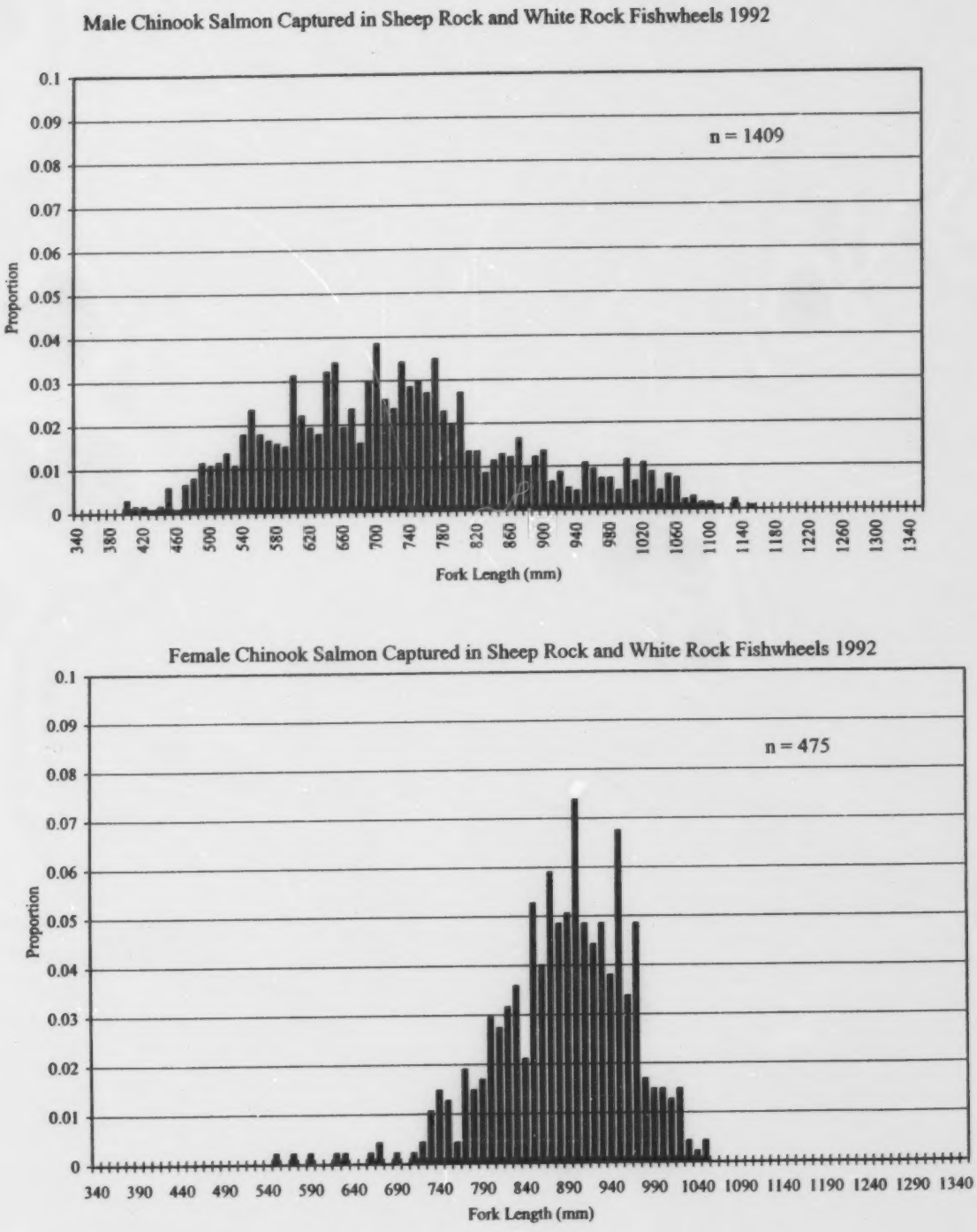

Male Chinook Salmon Captured in Sheep Rock and White Rock Fishwheels 1992
n = 1409
Proportion
Fork Length (mm)
Female Chinook Salmon Captured in Sheep Rock and White Rock Fishwheels 1992
n = 475
Proportion
Fork Length (mm)

Figure 17. Length frequency of combined Sheep Rock and White Rock fishwheel chinook salmon catches, 1992.

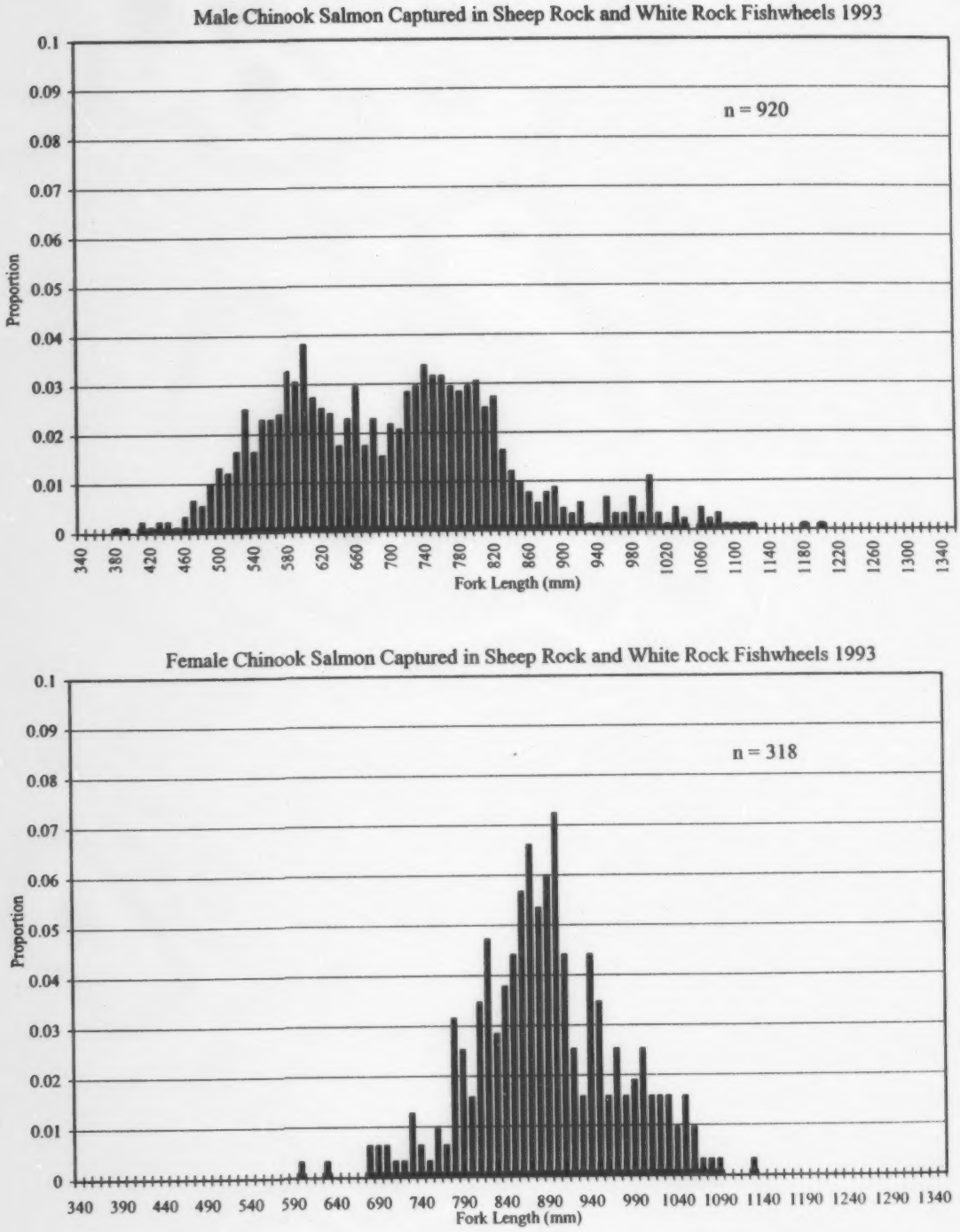
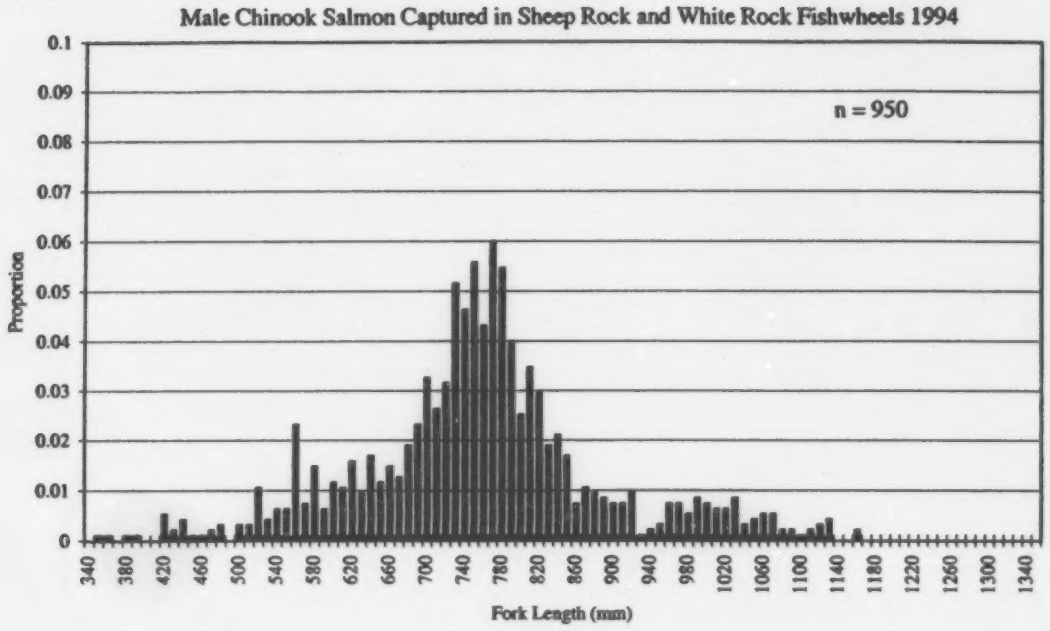


Figure 18. Length frequency of combined Sheep Rock and White Rock fishwheel chinook salmon catches, 1993.



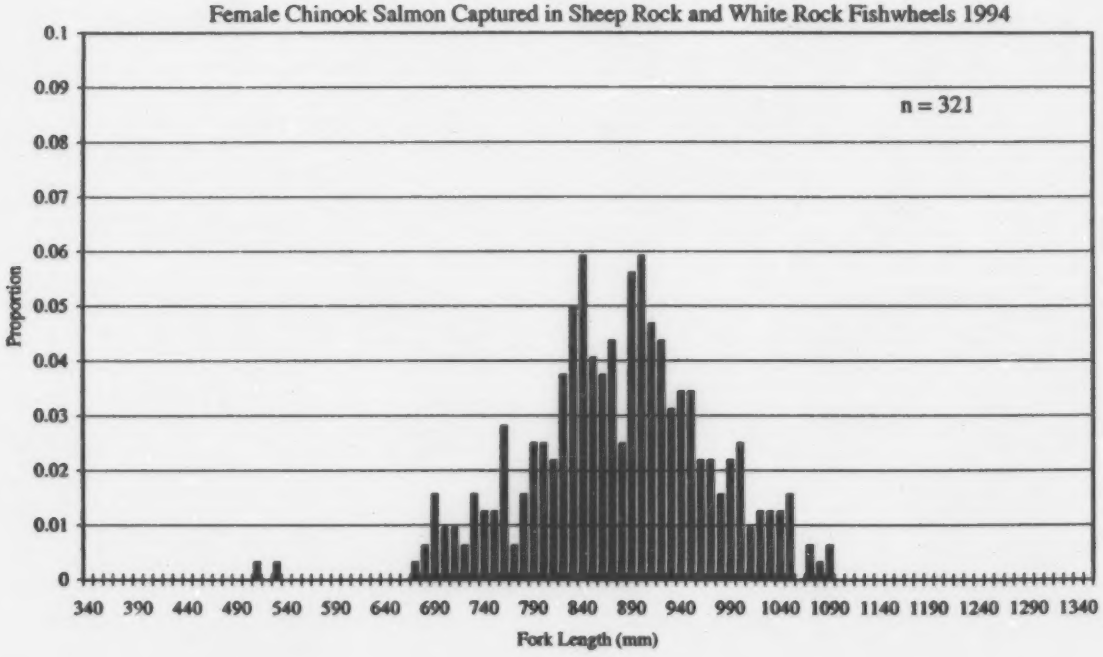


Fig. 19. Length frequency of combined Sheep Rock and White Rock fishwheel chinook salmon catches, 1994 .

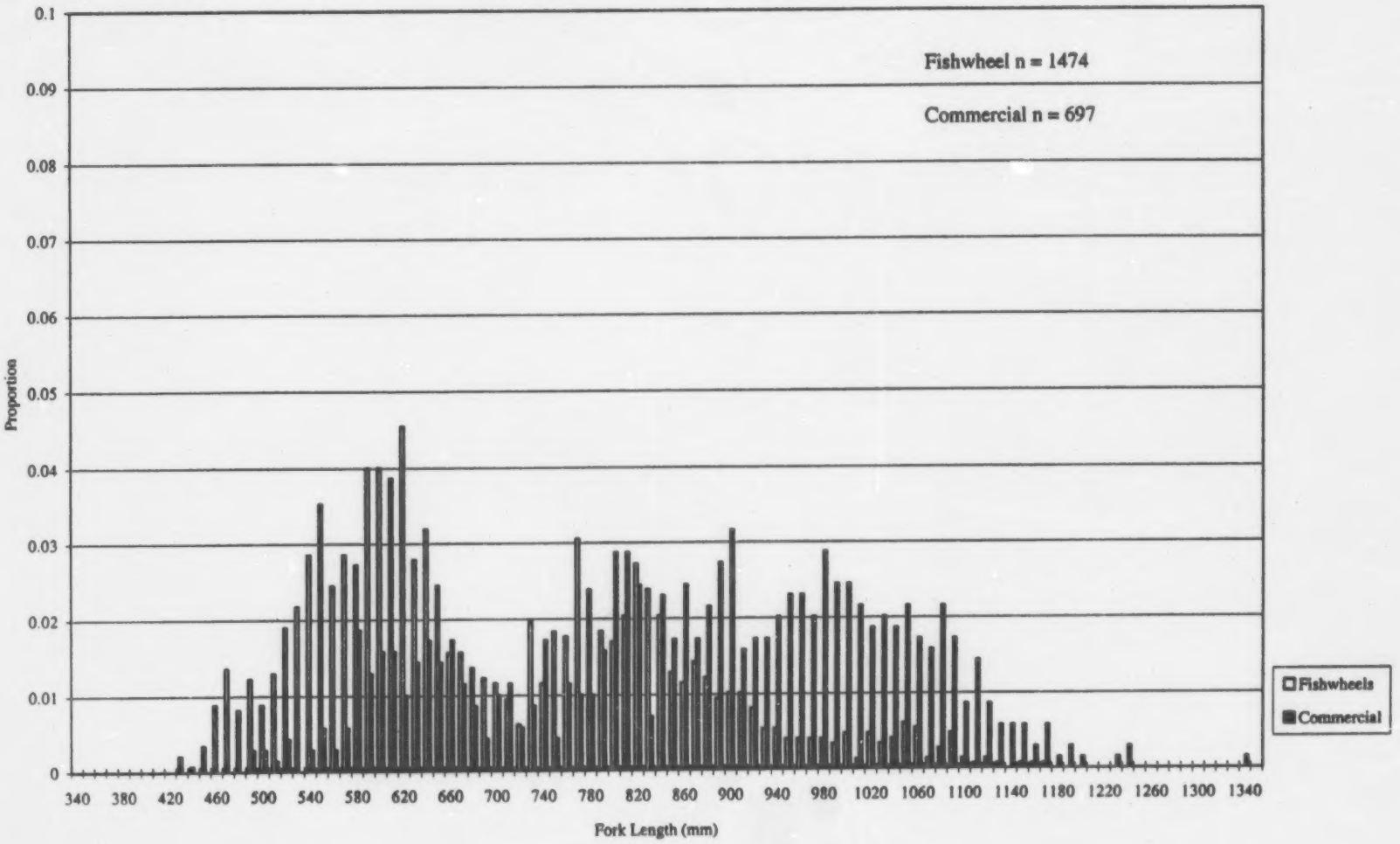


Figure 20. Length frequency of 1995 Sheep Rock and White Rock fishwheel male chinook salmon catches and of the 697 male chinook salmon in the 1995 commercial fishery sample (total n = 1353). One length record (940 mm) in the commercial fishery catch sample was of unknown sex and therefore is not plotted here.

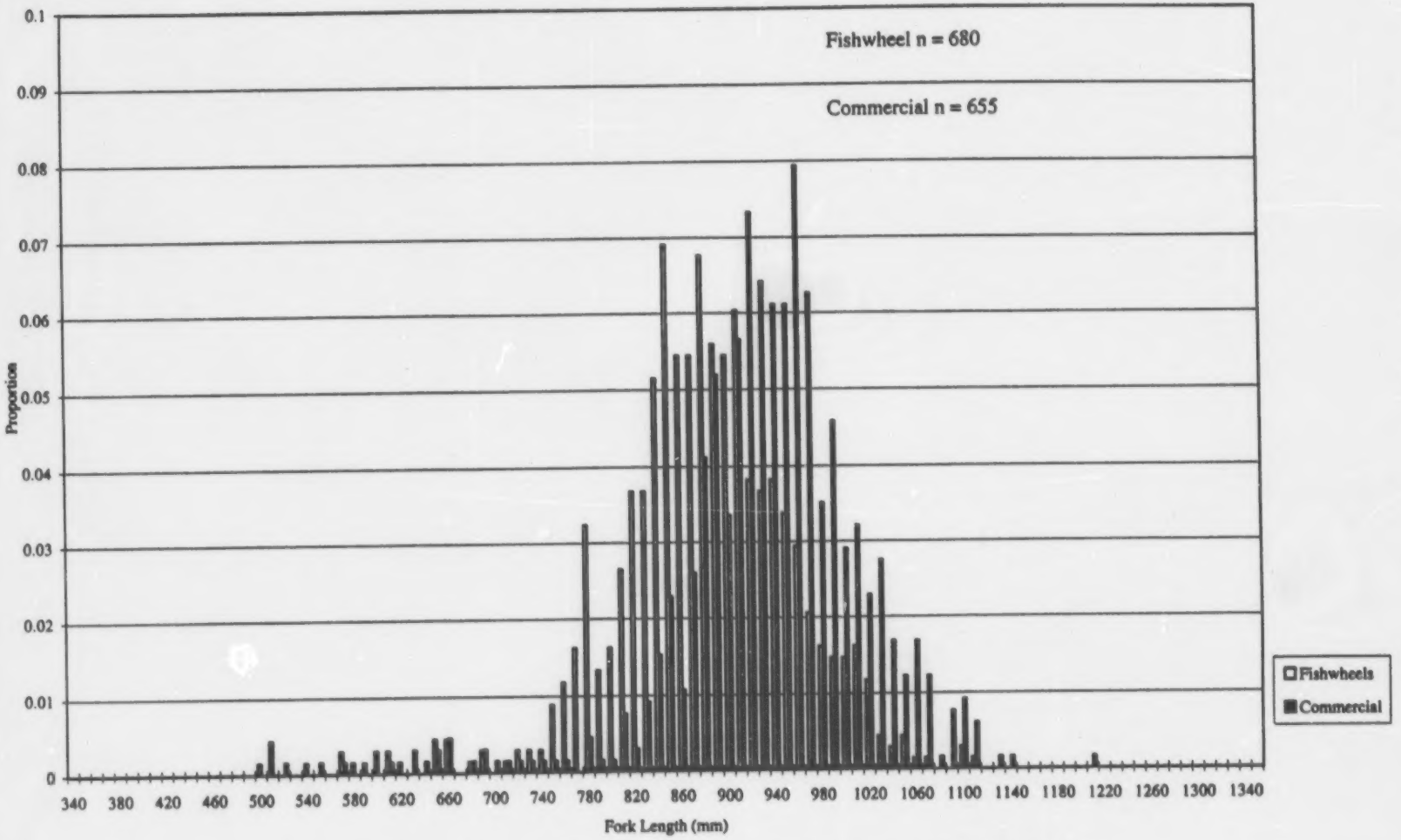


Figure 21. Length frequency of 1995 Sheep Rock and White Rock fishwheel female chinook salmon catches and of the 655 female chinook salmon in the 1995 commercial fishery sample (total n = 1353). One length record (940 mm) in the commercial fishery catch sample was of unknown sex and therefore is not plotted here.

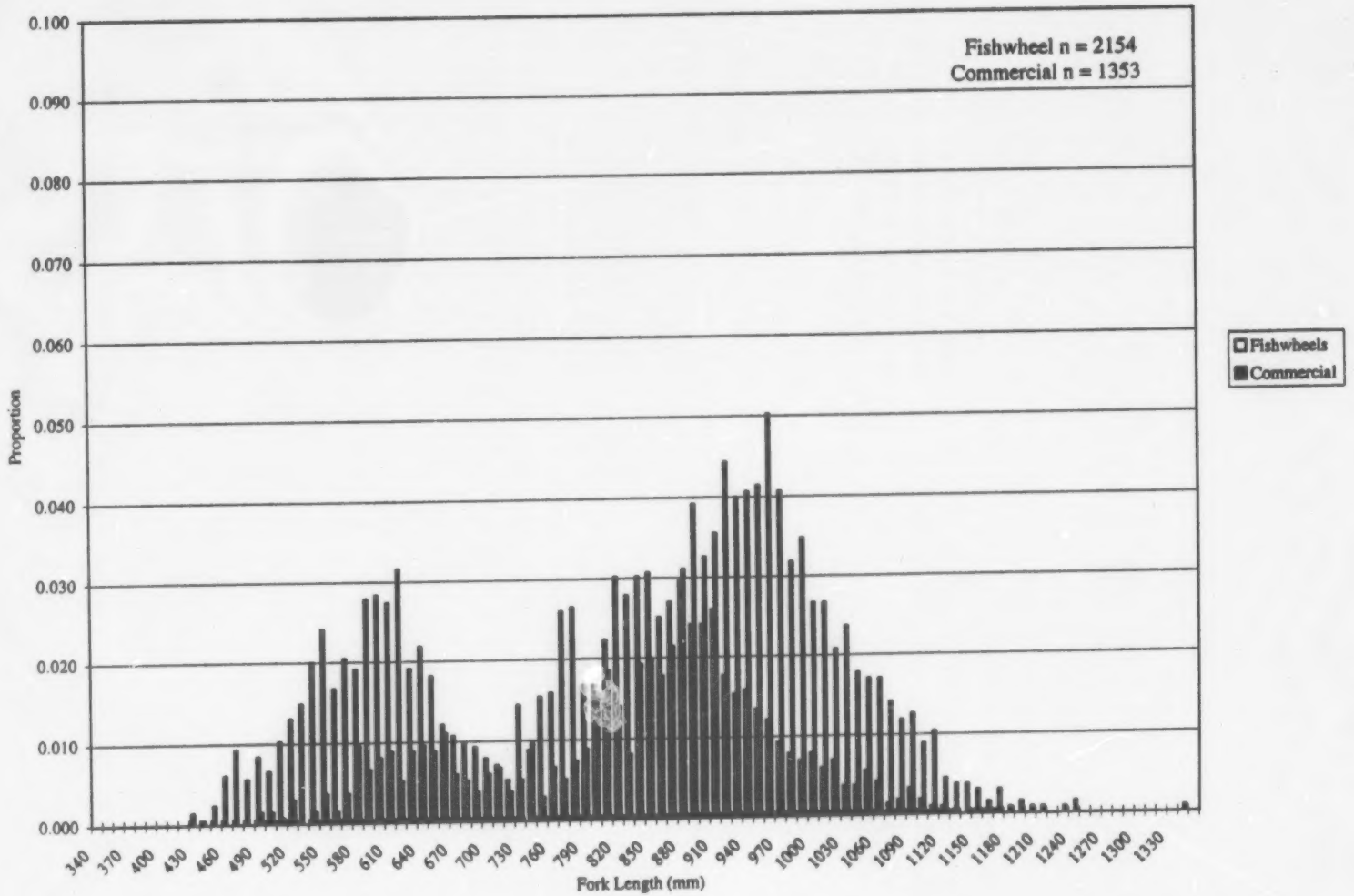


Figure 22. Length frequency of combined Sheep Rock and White Rock fishwheel chinook salmon catches, males and females together, 1995 and of the 1995 commercial fishery catch sample (n = 1353).

Appendix 1. Bibliography of Canadian Yukon River chinook salmon stock-assessment studies.

Brannian, L. K. November 1990. Estimates of total abundance, exploitation rate, and migratory timing of chinook salmon runs in the Yukon River 1982 - 1986. Fishery Research Bulletin No. 90-03. Alaska Department of Fish and Game.

Brannian, L. K. November 1986. A review of population estimates of Yukon River salmon based on mark and recapture data. Alaska Department of Fish and Game.

Bromaghin, J. F. September 1990. A comprehensive review of the Yukon River salmon tagging program conducted by the Canadian Department of Fisheries and Oceans. Regional Information Report No. 3A90-24. Alaska Department of Fish and Game.

Milligan, P.A., W.O. Rublee, D.D. Cornett and R.A.C. Johnston. August 1985. The distribution and abundance of chinook salmon (Oncorhynchus tshawytscha) in the upper Yukon river basin as determined by a radio-tagging and spaghetti tagging program: 1982-1983. DFO, Whitehorse, Yukon.

Annual Reports

Age, Sex and Size of Yukon River Salmon Catches and Escapements. Alaska Department of Fish and Game. Anchorage, Alaska.

Annual Management Report, Yukon Area. Alaska Department of Fish and Game. Anchorage, Alaska.

Origins of Chinook Salmon in the Yukon River Fisheries. Alaska Department of Fish and Game. Anchorage, Alaska.

Yukon River Salmon Season Review and Technical Committee Report. The United States/ Canada Yukon River Joint Technical Committee.

Appendix 2. Historic Canadian Catches And Escapements, 1980-1995

Canadian catches and estimated harvest rates of chinook salmon in the Yukon River drainage, 1980 to 1995.

	Upper Yukon Catch					Old Crow Aboriginal Catch	Total Yukon Aboriginal Catch	Total Canadian Catch	Upper Yukon Escapement		Harvest Rates				
Year	Commercial	Aboriginal	Domestic	Recreational	Total				Border	Spawning	Commercial	Aboriginal	Domestic	Recreational	Overall
1980	9500	7546	3500	300	20846	2000	9546	22846	58740	37894	0.162	0.128	0.060	0.005	0.355
1981	8593	8879	237	300	18009	100	8979	18109	70662	52653	0.122	0.126	0.003	0.004	0.255
1982	8640	7433	435	300	16808	400	7833	17208	36598	19790	0.236	0.203	0.012	0.008	0.459
1983	13027	5025	400	300	18752	200	5225	18952	47741	28989	0.273	0.105	0.008	0.006	0.393
1984	9885	5850	260	300	16295	500	6350	16795	43911	27616	0.225	0.133	0.006	0.007	0.371
1985	12573	5800	478	300	19151	150	5950	19301	29881	10730	0.421	0.194	0.016	0.010	0.641
1986	10797	8625	342	300	20064	300	8925	20364	36479	16415	0.296	0.236	0.009	0.008	0.550
1987	10864	6069	330	300	17563	51	6120	17614	30823	13260	0.352	0.197	0.011	0.010	0.570
1988	13217	7178	282	650	21327	100	7278	21427	44445	23118	0.297	0.162	0.006	0.015	0.480
1989	9789	6930	400	300	17419	525	7455	17944	42620	25201	0.230	0.163	0.009	0.007	0.409
1990	11324	7109	247	300	18980	247	7356	19227	56679	37699	0.200	0.125	0.004	0.005	0.335
1991	10906	9011	227	300	20444	163	9174	20607	41187	20743	0.265	0.219	0.006	0.007	0.496
1992	10877	6349	277	300	17803	100	6449	17903	43185	25382	0.252	0.147	0.006	0.007	0.412
1993	10350	5576	243	300	16469	142	5718	16611	45027	28558	0.230	0.124	0.005	0.007	0.366
1994	12028	8089	373	300	20790	428	8517	21218	45231	24441	0.266	0.179	0.008	0.007	0.460
1995	11146	7945	300	700	20091	796	8741	20887	52353	33262	0.213	0.152	0.006	0.013	0.384

- Upper Yukon Border Escapement and Spawning Escapement exclude the Porcupine stocks.
-1982-83 and 1985-91 spawning escapement estimates are from DFO tagging data. 1980-81 escapements were calculated using a five area escapement index count (Tatchun, Big Salmon, Nisutlin and Wolf Rivers and non-hatchery Whitehorse Rapids Fishway) for these years expanded by the average proportion the index represented of the total escapement (from DFO tagging) for the period 1982-83, 1985-89.
-The 1984 escapement was calculated using a five area escapement index count (Tatchun, Big Salmon, Nisutlin and Wolf Rivers and non-hatchery Whitehorse Rapids Fishway) for this year expanded by the average proportion the index represented of the total escapement (from DFO tagging) for the period 1982-83, 1985-90.
-The 1991 & 1992 Upper Yukon aboriginal fishery catches were estimated by expanding the Dawson and Teslin catch by the average proportion these catches represented respectively in 1989-90.

Appendix 3. Statistical week ending dates, 1990 - 1995. Statistical weeks began at 00:00 hours on a Sunday and ended at 24:00 hours on a Saturday.

	Year						
Statistical Week	1990	1991	1992	1993	1994	1995	Average 1990 - 1995
18	05 May	04 May	02 May	01 May	30 Apr	06 May	03 May
19	12 May	11 May	09 May	08 May	07 May	13 May	10 May
20	19 May	18 May	16 May	15 May	14 May	20 May	17 May
21	26 May	25 May	23 May	22 May	21 May	27 May	24 May
22	02 Jun	01 Jun	30 May	29 May	28 May	03 Jun	31 May
23	09 Jun	08 Jun	06 Jun	05 Jun	04 Jun	10 Jun	07 Jun
24	16 Jun	15 Jun	13 Jun	12 Jun	11 Jun	17 Jun	14 Jun
25	23 Jun	22 Jun	20 Jun	19 Jun	18 Jun	24 Jun	21 Jun
26	30 Jun	29 Jun	27 Jun	26 Jun	25 Jun	01 Jul	28 Jun
27	07 Jul	06 Jul	04 Jul	03 Jul	02 Jul	08 Jul	05 Jul
28	14 Jul	13 Jul	11 Jul	10 Jul	09 Jul	15 Jul	12 Jul
29	21 Jul	20 Jul	18 Jul	17 Jul	16 Jul	22 Jul	19 Jul
30	28 Jul	27 Jul	25 Jul	24 Jul	23 Jul	29 Jul	26 Jul
31	04 Aug	03 Aug	01 Aug	31 Jul	30 Jul	05 Aug	02 Aug
32	11 Aug	10 Aug	08 Aug	07 Aug	06 Aug	12 Aug	09 Aug
33	18 Aug	17 Aug	15 Aug	14 Aug	13 Aug	19 Aug	16 Aug
34	25 Aug	24 Aug	22 Aug	21 Aug	20 Aug	26 Aug	23 Aug
35	01 Sep	31 Aug	29 Aug	28 Aug	27 Aug	02 Sep	30 Aug
36	08 Sep	07 Sep	05 Sep	04 Sep	03 Sep	09 Sep	06 Sep
37	15 Sep	14 Sep	12 Sep	11 Sep	10 Sep	16 Sep	13 Sep
38	22 Sep	21 Sep	19 Sep	18 Sep	17 Sep	23 Sep	20 Sep
39	29 Sep	28 Sep	26 Sep	25 Sep	24 Sep	30 Sep	27 Sep
40	06 Oct	05 Oct	03 Oct	02 Oct	01 Oct	07 Oct	04 Oct

Appendix 4. Daily and cumulative chinook counts at the Sheep Rock and White Rock tagging fishwheels,1990-1995. Note that the totals in this Appendix count table for all years except 1990 and 1993 do not match those in the raw data files. The latter were used in calculations in this report. The reason for these discrepancies is unknown. Due to high water conditions in 1992 the White Rock fishwheel was not in operation until July 2. The date the Sheep Rock fishwheel began operating in this year is unknown. The date the White Rock fishwheel began operating in 1990 is also unknown but it is assumed to have been before June 23. See Table 1 for fishwheel operation start dates from 1990 - 1995.

	1990		1991		1992		1993		1994		1995	
Date	Daily counts	Cumulative count	Daily counts	Cumulative count	Daily counts	Cumulative count	Daily counts	Cumulative count	Daily counts	Cumulative count	Daily counts	Cumulative count
23 Jun	0	0	0	0	n/a	n/a	1	1	0	0	0	0
24 Jun	0	0	0	0	n/a	n/a	3	4	1	1	0	0
25 Jun	0	0	0	0	n/a	n/a	1	5	0	1	1	1
26 Jun	0	0	0	0	n/a	n/a	2	7	0	1	1	2
27 Jun	0	0	0	0	n/a	n/a	7	14	0	1	0	2
28 Jun	0	0	2	2	n/a	n/a	5	19	1	2	2	4
29 Jun	1	1	1	3	n/a	n/a	7	26	1	3	2	6
30 Jun	2	3	2	5	n/a	n/a	8	34	1	4	2	8
01 Jul	3	6	4	9	n/a	n/a	18	52	9	13	1	9
02 Jul	0	6	5	14	0	0	19	71	3	16	5	14
03 Jul	7	13	7	21	0	0	35	106	11	27	2	16
04 Jul	9	22	16	37	0	0	23	129	9	36	12	28
05 Jul	6	28	8	45	0	0	27	156	23	59	17	45
06 Jul	5	33	23	68	0	0	34	190	15	74	17	62
07 Jul	15	48	23	91	0	0	28	218	15	89	17	79
08 Jul	8	56	29	120	0	0	63	281	21	110	18	97
09 Jul	20	76	51	171	0	0	30	311	26	136	21	118
10 Jul	24	100	25	196	0	0	34	345	27	163	38	156
11 Jul	25	125	61	257	0	0	32	377	20	183	18	174
12 Jul	30	155	71	328	0	0	41	418	41	224	42	216
13 Jul	30	185	53	381	0	0	37	455	72	296	48	264
14 Jul	33	218	31	412	2	2	39	494	63	359	60	324
15 Jul	44	262	27	439	4	6	38	532	45	404	68	392
16 Jul	63	325	26	465	18	24	33	565	57	461	73	465
17 Jul	71	396	60	525	30	54	26	591	35	496	98	563
18 Jul	72	468	49	574	40	94	37	628	58	554	67	630
19 Jul	78	546	41	615	47	141	32	660	45	599	47	677
20 Jul	71	617	43	658	93	234	36	696	35	634	57	734
21 Jul	78	695	45	703	108	342	34	730	37	671	36	770
22 Jul	63	758	44	747	166	508	19	749	31	702	56	826
23 Jul	67	825	54	801	127	635	50	799	30	732	65	891

Appendix 4. (cont'd)

	1990		1991		1992		1993		1994		1995	
Date	Daily counts	Cumulative count	Daily counts	Cumulative count	Daily counts	Cumulative count	Daily counts	Cumulative count	Daily counts	Cumulative count	Daily counts	Cumulative count
24 Jul	67	892	48	849	126	761	38	837	22	754	67	958
25 Jul	49	941	21	870	83	844	24	861	31	785	109	1067
26 Jul	67	1008	20	890	91	935	33	894	28	813	122	1189
27 Jul	42	1050	38	928	112	1047	36	930	42	855	170	1359
28 Jul	42	1092	42	970	101	1148	24	954	32	887	113	1472
29 Jul	42	1134	34	1004	86	1234	30	984	44	931	78	1550
30 Jul	36	1170	31	1035	70	1304	26	1010	30	961	84	1634
31 Jul	32	1202	40	1075	63	1367	49	1059	25	986	72	1706
01 Aug	24	1226	51	1126	66	1433	26	1085	21	1007	48	1754
02 Aug	14	1240	50	1176	58	1491	27	1112	29	1036	76	1830
03 Aug	11	1251	35	1211	39	1530	14	1126	30	1066	76	1906
04 Aug	13	1264	55	1266	11	1541	8	1134	21	1087	47	1953
05 Aug	13	1277	86	1352	15	1556	10	1144	22	1109	40	1993
06 Aug	11	1288	156	1508	28	1584	18	1162	18	1127	28	2021
07 Aug	12	1300	62	1570	12	1596	9	1171	26	1153	28	2049
08 Aug	12	1312	26	1596	44	1640	11	1182	20	1173	16	2065
09 Aug	15	1327	33	1629	33	1673	6	1188	20	1193	21	2086
10 Aug	9	1336	28	1657	41	1714	6	1194	14	1207	21	2107
11 Aug	6	1342	18	1675	26	1740	4	1198	15	1222	17	2124
12 Aug	6	1348	10	1685	18	1758	5	1203	8	1230	14	2138
13 Aug	1	1349	8	1693	21	1779	5	1208	7	1237	19	2157
14 Aug	2	1351	9	1702	15	1794	1	1209	6	1243	9	2166
15 Aug	0	1351	5	1707	19	1813	6	1215	8	1251	9	2175
16 Aug	2	1353	2	1709	9	1822	4	1219	8	1259	4	2179
17 Aug	0	1353	5	1714	19	1841	2	1221	4	1263	9	2188
18 Aug	0	1353	2	1716	2	1843	0	1221	5	1268	2	2190
19 Aug	0	1353	4	1720	10	1853	2	1223	3	1271	4	2194
20 Aug	1	1354	5	1725	10	1863	1	1224	2	1273	4	2198
21 Aug	0	1354	0	1725	3	1866	1	1225	6	1279	1	2199
22 Aug	0	1354	0	1725	6	1872	1	1226	0	1279	4	2203
23 Aug	2	1356	0	1725	1	1873	1	1227	1	1280	3	2206
24 Aug	0	1356	0	1725	3	1876	1	1228	1	1281	1	2207
25 Aug	3	1359	0	1725	3	1879	1	1229	0	1281	2	2209
26 Aug	0	1359	0	1725	3	1882	2	1231	0	1281	1	2210
27 Aug	0	1359	1	1726	0	1882	2	1233	2	1283	0	2210
28 Aug	2	1361	0	1726	0	1882	1	1234	3	1286	1	2211
29 Aug	0	1361	0	1726	0	1882	0	1234	1	1287	2	2213
30 Aug	0	1361	0	1726	2	1884	0	1234	0	1287	0	2213

Appendix 4. (cont'd)

	1990		1991		1992		1993		1994		1995	
Date	Daily counts	Cumulative count	Daily counts	Cumulative count	Daily counts	Cumulative count	Daily counts	Cumulative count	Daily counts	Cumulative count	Daily counts	Cumulative count
31 Aug	0	1361	0	1726	0	1884	0	1234	0	1287	0	2213
01 Sep	0	1361	0	1726	2	1886	5	1239	0	1287	1	2214
02 Sep	0	1361	0	1726	0	1886	1	1240	0	1287	0	2214
03 Sep	0	1361	0	1726	1	1887	0	1240	2	1289	0	2214
04 Sep	0	1361	0	1726	0	1887	1	1241	0	1289	0	2214
05 Sep	0	1361	0	1726	0	1887	0	1241	0	1289	1	2215
06 Sep	0	1361	0	1726	1	1888	0	1241	0	1289	0	2215
07 Sep	0	1361	0	1726	0	1888	0	1241	0	1289	0	2215
08 Sep	0	1361	0	1726	0	1888	0	1241	0	1289	0	2215
09 Sep	0	1361	0	1726	1	1889	0	1241	0	1289	0	2215
10 Sep	0	1361	0	1726	0	1889	0	1241	0	1289	0	2215
11 Sep	0	1361	0	1726	0	1889	0	1241	0	1289	0	2215
12 Sep	0	1361	0	1726	0	1889	0	1241	0	1289	0	2215
13 Sep	0	1361	0	1726	0	1889	0	1241	0	1289	0	2215
14 Sep	0	1361	0	1726	0	1889	0	1241	0	1289	0	2215
15 Sep	0	1361	0	1726	0	1889	0	1241	0	1289	0	2215
16 Sep	0	1361	0	1726	0	1889	0	1241	0	1289	0	2215
17 Sep	0	1361	0	1726	0	1889	0	1241	0	1289	0	2215
18 Sep	0	1361	0	1726	0	1889	0	1241	0	1289	0	2215
19 Sep	0	1361	0	1726	0	1889	0	1241	0	1289	0	2215
20 Sep	0	1361	0	1726	0	1889	0	1241	0	1289	0	2215
21 Sep	0	1361	0	1726	0	1889	0	1241	0	1289	0	2215
22 Sep	0	1361	0	1726	0	1889	0	1241	0	1289	0	2215
23 Sep	0	1361	0	1726	0	1889	0	1241	0	1289	0	2215
24 Sep	0	1361	0	1726	0	1889	0	1241	0	1289	0	2215
25 Sep	0	1361	0	1726	0	1889	0	1241	1	1290	0	2215
26 Sep	0	1361	0	1726	0	1889	0	1241	0	1290	0	2215
Total	1361	1361	1726	1726	1889	1889	1241	1241	1290	1290	2215	2215

Appendix 5. Age composition by statistical week for chinook salmon captured in Sheep Rock and White Rock fishwheels, 1990 - 1995: males and females separately.

Table 1. Age composition by statistical week for chinook salmon captured in Sheep Rock and White Rock fishwheels 1990: males and females separately.

			Age class																			
			3^1		4^1		4^2		5^1		5^2		6^2		6^3		7^2		7^3		Total	
Week ending	Statistical week		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
7 Jul	26-27	n	0.0	0.0	0.0	0.0	7.0	0.0	0.0	1.0	14.0	2.0	4.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	7.0
		%	0.0%	0.0%	0.0%	0.0%	21.9%	0.0%	0.0%	3.1%	43.8%	6.3%	12.5%	12.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	78.1%	21.9%
14 Jul	28	n	0.0	0.0	0.0	0.0	21.0	2.0	0.0	0.0	20.0	16.0	4.0	22.0	0.0	1.0	0.0	0.0	0.0	0.0	45.0	41.0
		%	0.0%	0.0%	0.0%	0.0%	24.4%	2.3%	0.0%	0.0%	23.3%	18.6%	4.7%	25.6%	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%	52.3%	47.7%
21 Jul	29	n	0.0	0.0	1.0	1.0	88.0	1.0	1.0	1.0	86.0	10.0	23.0	53.0	1.0	0.0	3.0	3.0	1.0	0.0	204.0	69.0
		%	0.0%	0.0%	0.4%	0.4%	32.2%	0.4%	0.4%	0.4%	31.5%	3.7%	8.4%	19.4%	0.4%	0.0%	1.1%	1.1%	0.4%	0.0%	74.7%	25.3%
28 Jul	30	n	0.0	0.0	0.0	0.0	32.0	1.0	0.0	1.0	75.0	3.0	24.0	51.0	1.0	0.0	2.0	6.0	0.0	0.0	134.0	62.0
		%	0.0%	0.0%	0.0%	0.0%	16.3%	0.5%	0.0%	0.5%	38.3%	1.5%	12.2%	26.0%	0.5%	0.0%	1.0%	3.1%	0.0%	0.0%	68.4%	31.6%
04 Aug	31	n	1.0	0.0	0.0	0.0	24.0	0.0	0.0	0.0	23.0	2.0	15.0	27.0	0.0	0.0	2.0	4.0	0.0	0.0	65.0	33.0
		%	1.0%	0.0%	0.0%	0.0%	24.5%	0.0%	0.0%	0.0%	23.5%	2.0%	15.3%	27.6%	0.0%	0.0%	2.0%	4.1%	0.0%	0.0%	66.3%	33.7%
01 Sep	32-35	n	0.0	0.0	0.0	0.0	9.0	0.0	1.0	0.0	3.0	4.0	2.0	15.0	0.0	0.0	0.0	3.0	0.0	0.0	15.0	22.0
		%	0.0%	0.0%	0.0%	0.0%	24.3%	0.0%	2.7%	0.0%	8.1%	10.8%	5.4%	40.5%	0.0%	0.0%	0.0%	8.1%	0.0%	0.0%	40.5%	59.5%
Combined weeks		N	1.0	0.0	1.0	1.0	181.0	4.0	2.0	3.0	221.0	37.0	72.0	172.0	2.0	1.0	7.0	16.0	1.0	0.0	488.0	234.0
		%	0.1%	0.0%	0.1%	0.1%	25.1%	0.6%	0.3%	0.4%	30.6%	5.1%	10.0%	23.8%	0.3%	0.1%	1.0%	2.2%	0.1%	0.0%	67.6%	32.4%

Appendix 5. (cont'd)

Table 2. Age composition by statistical week for chinook salmon captured in Sheep Rock and White Rock fishwheels 1991: males and females separately.

			Age class																					
			3^1		4^1		4^2		5^1		5^2		6^1		6^2		6^3		7^2		7^3		Total	
Week ending	Statistical week		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
7 Jul	26-27	n	0.0	0.0	1.0	0.0	3.0	0.0	0.0	0.0	22.0	9.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	26.0	10.0
		%	0.0%	0.0%	2.8%	0.0%	8.3%	0.0%	0.0%	0.0%	61.1%	25.0%	0.0%	0.0%	0.0%	2.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	72.2%	27.8%
14 Jul	28	n	0.0	0.0	2.0	3.0	1.0	0.0	0.0	0.0	85.0	70.0	0.0	0.0	3.0	14.0	1.0	0.0	1.0	3.0	0.0	0.0	93.0	90.0
		%	0.0%	0.0%	1.1%	1.6%	0.5%	0.0%	0.0%	0.0%	46.4%	38.3%	0.0%	0.0%	1.6%	7.7%	0.5%	0.0%	0.5%	1.6%	0.0%	0.0%	50.8%	49.2%
21 Jul	29	n	0.0	0.0	3.0	0.0	17.0	2.0	2.0	0.0	83.0	20.0	0.0	0.0	8.0	20.0	0.0	0.0	1.0	7.0	0.0	0.0	114.0	49.0
		%	0.0%	0.0%	1.8%	0.0%	10.4%	1.2%	1.2%	0.0%	50.9%	12.3%	0.0%	0.0%	4.9%	12.3%	0.0%	0.0%	0.6%	4.3%	0.0%	0.0%	69.9%	30.1%
28 Jul	30	n	2.0	0.0	1.0	0.0	18.0	0.0	3.0	5.0	77.0	20.0	0.0	2.0	6.0	33.0	0.0	0.0	1.0	3.0	1.0	1.0	109.0	64.0
		%	1.2%	0.0%	0.6%	0.0%	10.4%	0.0%	1.7%	2.9%	44.5%	11.6%	0.0%	1.2%	3.5%	19.1%	0.0%	0.0%	0.6%	1.7%	0.6%	0.6%	63.0%	37.0%
04 Aug	31	n	0.0	0.0	2.0	1.0	24.0	1.0	1.0	0.0	61.0	12.0	0.0	0.0	14.0	56.0	0.0	0.0	5.0	13.0	0.0	0.0	107.0	83.0
		%	0.0%	0.0%	1.1%	0.5%	12.6%	0.5%	0.5%	0.0%	32.1%	6.3%	0.0%	0.0%	7.4%	29.5%	0.0%	0.0%	2.6%	6.8%	0.0%	0.0%	56.3%	43.7%
01 Sep	32	n	3.0	0.0	1.0	0.0	34.0	0.0	0.0	4.0	45.0	19.0	0.0	1.0	35.0	105.0	0.0	0.0	10.0	26.0	0.0	0.0	128.0	155.0
		%	1.1%	0.0%	0.4%	0.0%	12.0%	0.0%	0.0%	1.4%	15.9%	6.7%	0.0%	0.4%	12.4%	37.1%	0.0%	0.0%	3.5%	9.2%	0.0%	0.0%	45.2%	54.8%
	33 - 35	n	0.0	0.0	0.0	0.0	8.0	0.0	1.0	1.0	5.0	5.0	0.0	0.0	7.0	11.0	0.0	0.0	3.0	6.0	0.0	0.0	24.0	23.0
		%	0.0%	0.0%	0.0%	0.0%	17.0%	0.0%	2.1%	2.1%	10.6%	10.6%	0.0%	0.0%	14.9%	23.4%	0.0%	0.0%	6.4%	12.8%	0.0%	0.0%	51.1%	48.9%
Combined weeks		N	5.0	0.0	10.0	4.0	105.0	3.0	7.0	10.0	378.0	155.0	0.0	3.0	73.0	240.0	1.0	0.0	21.0	58.0	1.0	1.0	601.0	474.0
		%	0.5%	0.0%	0.9%	0.4%	9.8%	0.3%	0.7%	0.9%	35.2%	14.4%	0.0%	0.3%	6.8%	22.3%	0.1%	0.0%	2.0%	5.4%	0.1%	0.1%	55.9%	44.1%

Appendix 5. (cont'd)

Table 3. Age composition by statistical week for chinook salmon captured in Sheep Rock and White Rock fishwheels 1992: males and females separately.

			Age class																					
			3^1		4^1		4^2		5^1		5^2		6^1		6^2		6^3		7^2		7^3		Total	
Week ending	Statistical week		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
18 Jul	29	n	0.0	0.0	2.0	1.0	1.0	0.0	0.0	0.0	23.0	6.0	0.0	0.0	15.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	41.0	18.0
		%	0.0%	0.0%	3.4%	1.7%	1.7%	0.0%	0.0%	0.0%	39.0%	10.2%	0.0%	0.0%	25.4%	18.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	69.5%	30.5%
25 Jul	30	n	0.0	0.0	11.0	1.0	49.0	4.0	3.0	4.0	144.0	24.0	0.0	0.0	138.0	95.0	2.0	0.0	1.0	1.0	2.0	0.0	350.0	129.0
		%	0.0%	0.0%	2.3%	0.2%	10.2%	0.8%	0.6%	0.8%	30.1%	5.0%	0.0%	0.0%	28.8%	19.8%	0.4%	0.0%	0.2%	0.2%	0.4%	0.0%	73.1%	26.9%
15 Aug	31 - 33	n	0.0	0.0	1.0	0.0	16.0	1.0	1.0	1.0	10.0	2.0	0.0	1.0	10.0	20.0	0.0	0.0	1.0	2.0	0.0	0.0	39.0	27.0
		%	0.0%	0.0%	1.5%	0.0%	24.2%	1.5%	1.5%	1.5%	15.2%	3.0%	0.0%	1.5%	15.2%	30.3%	0.0%	0.0%	1.5%	3.0%	0.0%	0.0%	59.1%	40.9%
05 Sep	34 - 36	n	1.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	6.0	2.0	0.0	0.0	4.0	7.0	0.0	0.0	1.0	1.0	0.0	0.0	14.0	10.0
		%	4.2%	0.0%	0.0%	0.0%	8.3%	0.0%	0.0%	0.0%	25.0%	8.3%	0.0%	0.0%	16.7%	29.2%	0.0%	0.0%	4.2%	4.2%	0.0%	0.0%	58.3%	41.7%
Combined weeks		N	1.0	0.0	14.0	2.0	68.0	5.0	4.0	5.0	183.0	34.0	0.0	1.0	167.0	133.0	2.0	0.0	3.0	4.0	2.0	0.0	444.0	184.0
		%	0.2%	0.0%	2.2%	0.3%	10.8%	0.8%	0.6%	0.8%	29.1%	5.4%	0.0%	0.2%	26.6%	21.2%	0.3%	0.0%	0.5%	0.6%	0.3%	0.0%	70.7%	29.3%

Appendix 5. (cont'd)

Table 4. Age composition by statistical week for chinook salmon captured in Sheep Rock and White Rock fishwheels 1993: males and females separately. (M) is male and (F) is female.

			Age class																							
			3^1		3^2		4^1		4^2		5^1		5^2		53		61		6^2		6^3		7^2		Total	
Week ending	Statistical week		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
3 Jul	26 - 27	n	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	1.0	2.0	32.0	2.0	0.0	0.0	0.0	0.0	8.0	8.0	0.0	0.0	1.0	1.0	50.0	13.0
		%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	12.7%	0.0%	1.6%	3.2%	50.8%	3.2%	0.0%	0.0%	0.0%	0.0%	12.7%	12.7%	0.0%	0.0%	1.6%	1.6%	79.4%	20.6%
10 Jul	28	n	1.0	0.0	0.0	0.0	1.0	0.0	30.0	0.0	5.0	2.0	68.0	10.0	0.0	0.0	0.0	0.0	18.0	20.0	1.0	0.0	0.0	2.0	124.0	34.0
		%	0.6%	0.0%	0.0%	0.0%	0.6%	0.0%	19.0%	0.0%	3.2%	1.3%	43.0%	6.3%	0.0%	0.0%	0.0%	0.0%	11.4%	12.7%	0.6%	0.0%	0.0%	1.3%	78.5%	21.5%
17 Jul	29	n	3.0	0.0	0.0	0.0	3.0	0.0	52.0	0.0	2.0	5.0	49.0	5.0	1.0	0.0	1.0	0.0	12.0	24.0	0.0	0.0	0.0	2.0	123.0	36.0
		%	1.9%	0.0%	0.0%	0.0%	1.9%	0.0%	32.7%	0.0%	1.3%	3.1%	30.8%	3.1%	0.6%	0.0%	0.6%	0.0%	7.5%	15.1%	0.0%	0.0%	0.0%	1.3%	77.4%	22.6%
24 Jul	30	n	1.0	0.0	0.0	0.0	2.0	0.0	34.0	0.0	3.0	5.0	45.0	6.0	0.0	0.0	1.0	3.0	11.0	28.0	0.0	0.0	0.0	5.0	97.0	47.0
		%	0.7%	0.0%	0.0%	0.0%	1.4%	0.0%	23.6%	0.0%	2.1%	3.5%	31.3%	4.2%	0.0%	0.0%	0.7%	2.1%	7.6%	19.4%	0.0%	0.0%	0.0%	3.5%	67.4%	32.6%
31 Jul	31	n	5.0	0.0	0.0	0.0	3.0	0.0	51.0	1.0	1.0	3.0	24.0	2.0	0.0	0.0	1.0	2.0	12.0	13.0	0.0	0.0	0.0	7.0	97.0	28.0
		%	4.0%	0.0%	0.0%	0.0%	2.4%	0.0%	40.8%	0.8%	0.8%	2.4%	19.2%	1.6%	0.0%	0.0%	0.8%	1.6%	9.6%	10.4%	0.0%	0.0%	0.0%	5.6%	77.6%	22.4%
07 Aug	32	n	2.0	0.0	1.0	0.0	0.0	0.0	30.0	0.0	0.0	3.0	5.0	3.0	0.0	0.0	0.0	1.0	9.0	10.0	0.0	0.0	1.0	1.0	48.0	18.0
		%	3.0%	0.0%	1.5%	0.0%	0.0%	0.0%	45.5%	0.0%	0.0%	4.5%	7.6%	4.5%	0.0%	0.0%	0.0%	1.5%	13.6%	15.2%	0.0%	0.0%	1.5%	1.5%	72.7%	27.3%
28 Aug	33 - 35	n	2.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	1.0	4.0	5.0	1.0	0.0	0.0	0.0	0.0	4.0	8.0	0.0	0.0	0.0	2.0	32.0	15.0
		%	4.3%	0.0%	0.0%	0.0%	0.0%	0.0%	42.6%	0.0%	2.1%	8.5%	10.6%	2.1%	0.0%	0.0%	0.0%	0.0%	8.5%	17.0%	0.0%	0.0%	0.0%	4.3%	68.1%	31.9%
Combined weeks		N	14.0	0.0	1.0	0.0	9.0	0.0	225.0	1.0	13.0	24.0	228.0	29.0	1.0	0.0	3.0	6.0	74.0	111.0	1.0	0.0	2.0	20.0	571.0	191.0
		%	1.8%	0.0%	0.1%	0.0%	1.2%	0.0%	29.5%	0.1%	1.7%	3.1%	29.9%	3.8%	0.1%	0.0%	0.4%	0.8%	9.7%	14.6%	0.1%	0.0%	0.3%	2.6%	74.9%	25.1%

Appendix 5. (cont'd)

Table 5. Age composition by statistical week for chinook salmon captured in Sheep Rock and White Rock fishwheels 1994 males and females separately.

			Age class																					
			3^1		32		4^1		4^2		5^1		5^2		61		6^2		7^2		7^3		Total	
Week ending	Statistical week		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
09 Jul	26 - 28	n	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	62.0	23.0	0.0	0.0	7.0	5.0	0.0	2.0	0.0	0.0	71.0	30.0
		%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	61.4%	22.8%	0.0%	0.0%	6.9%	5.0%	0.0%	2.0%	0.0%	0.0%	70.3%	29.7%
16 Jul	29	n	0.0	0.0	1.0	0.0	5.0	0.0	12.0	0.0	0.0	0.0	158.0	11.0	1.0	1.0	23.0	17.0	0.0	0.0	0.0	1.0	200.0	30.0
		%	0.0%	0.0%	0.4%	0.0%	2.2%	0.0%	5.2%	0.0%	0.0%	0.0%	68.7%	4.8%	0.4%	0.4%	10.0%	7.4%	0.0%	0.0%	0.0%	0.4%	87.0%	13.0%
23 Jul	30	n	1.0	0.0	1.0	0.0	4.0	0.0	17.0	0.0	0.0	1.0	70.0	10.0	1.0	0.0	28.0	27.0	3.0	3.0	0.0	1.0	125.0	42.0
		%	0.6%	0.0%	0.6%	0.0%	2.4%	0.0%	10.2%	0.0%	0.0%	0.6%	41.9%	6.0%	0.6%	0.0%	16.8%	16.2%	1.8%	1.8%	0.0%	0.6%	74.9%	25.1%
30 Jul	31	n	4.0	0.0	4.0	0.0	1.0	0.0	15.0	0.0	2.0	0.0	49.0	3.0	0.0	3.0	16.0	28.0	3.0	3.0	0.0	0.0	94.0	37.0
		%	3.1%	0.0%	3.1%	0.0%	0.8%	0.0%	11.5%	0.0%	1.5%	0.0%	37.4%	2.3%	0.0%	2.3%	12.2%	21.4%	2.3%	2.3%	0.0%	0.0%	71.8%	28.2%
06 Aug	32	n	1.0	0.0	3.0	0.0	2.0	0.0	13.0	0.0	0.0	8.0	31.0	0.0	0.0	0.0	16.0	16.0	3.0	7.0	0.0	0.0	69.0	31.0
		%	1.0%	0.0%	3.0%	0.0%	2.0%	0.0%	13.0%	0.0%	0.0%	8.0%	31.0%	0.0%	0.0%	0.0%	16.0%	16.0%	3.0%	7.0%	0.0%	0.0%	69.0%	31.0%
13 Aug	33	n	5.0	0.0	10.0	0.0	2.0	0.0	6.0	0.0	0.0	1.0	13.0	6.0	0.0	1.0	5.0	16.0	2.0	4.0	0.0	0.0	43.0	28.0
		%	7.0%	0.0%	14.1%	0.0%	2.8%	0.0%	8.5%	0.0%	0.0%	1.4%	18.3%	8.5%	0.0%	1.4%	7.0%	22.5%	2.8%	5.6%	0.0%	0.0%	60.6%	39.4%
10 Sep	34 - 37	n	0.0	0.0	4.0	0.0	1.0	0.0	4.0	0.0	1.0	2.0	4.0	1.0	1.0	0.0	1.0	8.0	2.0	1.0	0.0	0.0	18.0	12.0
		%	0.0%	0.0%	13.3%	0.0%	3.3%	0.0%	13.3%	0.0%	3.3%	6.7%	13.3%	3.3%	3.3%	0.0%	3.3%	26.7%	6.7%	3.3%	0.0%	0.0%	60.0%	40.0%
Combined weeks																								
		N	11.0	0.0	23.0	0.0	17.0	0.0	67.0	0.0	3.0	12.0	387.0	54.0	3.0	5.0	96.0	117.0	13.0	20.0	0.0	2.0	620.0	210.0
		%	1.3%	0.0%	2.8%	0.0%	2.0%	0.0%	8.1%	0.0%	0.4%	1.4%	46.6%	6.5%	0.4%	0.6%	11.6%	14.1%	1.6%	2.4%	0.0%	0.2%	74.7%	25.3%

Appendix 5. (cont'd)

Table 6. Age composition by statistical week for chinook salmon captured in Sheep Rock and White Rock fishwheels 1995 males and females separately. (M) is male and (F) is female.

			Age class																							
			3^1		32		4^1		4^2		5^1		5^2		5^3		6^1		6^2		7^2		7^3		Total	
Week ending	Statistical week		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
08 Jul	26-27	n	1.0	0.0	0.0	0.0	0.0	2.0	8.0	0.0	0.0	0.0	7.0	3.0	0.0	0.0	0.0	0.0	1.0	11.0	3.0	0.0	0.0	0.0	20.0	16.0
		%	2.8%	0.0%	0.0%	0.0%	0.0%	5.6%	22.2%	0.0%	0.0%	0.0%	19.4%	8.3%	0.0%	0.0%	0.0%	0.0%	2.8%	30.6%	8.3%	0.0%	0.0%	0.0%	55.6%	44.4%
15 Jul	28	n	3.0	0.0	0.0	0.0	3.0	0.0	24.0	1.0	1.0	0.0	12.0	6.0	0.0	0.0	0.0	0.0	21.0	30.0	2.0	0.0	0.0	0.0	66.0	37.0
		%	2.9%	0.0%	0.0%	0.0%	2.9%	0.0%	23.3%	1.0%	1.0%	0.0%	11.7%	5.8%	0.0%	0.0%	0.0%	0.0%	20.4%	29.1%	1.9%	0.0%	0.0%	0.0%	64.1%	35.9%
22 Jul	29	n	3.0	0.0	0.0	0.0	2.0	0.0	35.0	0.0	2.0	4.0	16.0	3.0	0.0	0.0	0.0	0.0	32.0	34.0	2.0	2.0	0.0	0.0	92.0	43.0
		%	2.2%	0.0%	0.0%	0.0%	1.5%	0.0%	25.9%	0.0%	1.5%	3.0%	11.9%	2.2%	0.0%	0.0%	0.0%	0.0%	23.7%	25.2%	1.5%	1.5%	0.0%	0.0%	68.1%	31.9%
29 Jul	30	n	2.0	0.0	0.0	0.0	4.0	1.0	78.0	2.0	4.0	5.0	25.0	6.0	1.0	0.0	0.0	0.0	33.0	53.0	3.0	7.0	0.0	0.0	150.0	74.0
		%	0.9%	0.0%	0.0%	0.0%	1.8%	0.4%	34.8%	0.9%	1.8%	2.2%	11.2%	2.7%	0.4%	0.0%	0.0%	0.0%	14.7%	23.7%	1.3%	3.1%	0.0%	0.0%	67.0%	33.0%
05 Aug	31	n	7.0	0.0	3.0	0.0	4.0	0.0	68.0	0.0	3.0	1.0	15.0	4.0	0.0	0.0	0.0	1.0	15.0	26.0	1.0	2.0	0.0	1.0	116.0	35.0
		%	4.6%	0.0%	2.0%	0.0%	2.6%	0.0%	45.0%	0.0%	2.0%	0.7%	9.9%	2.6%	0.0%	0.0%	0.0%	0.7%	9.9%	17.2%	0.7%	1.3%	0.0%	0.7%	76.8%	23.2%
12 Aug	32	n	1.0	0.0	2.0	1.0	0.0	0.0	12.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	2.0	7.0	0.0	0.0	0.0	0.0	17.0	9.0
		%	3.8%	0.0%	7.7%	3.8%	0.0%	0.0%	46.2%	0.0%	0.0%	0.0%	0.0%	3.8%	0.0%	0.0%	0.0%	0.0%	7.7%	26.9%	0.0%	0.0%	0.0%	0.0%	65.4%	34.6%
02 Sep	33-35	n	0.0	0.0	0.0	0.0	2.0	0.0	6.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	5.0	0.0	1.0	0.0	0.0	10.0	7.0
		%	0.0%	0.0%	0.0%	0.0%	11.8%	0.0%	35.3%	0.0%	0.0%	5.9%	5.9%	0.0%	0.0%	0.0%	0.0%	0.0%	5.9%	29.4%	0.0%	5.9%	0.0%	0.0%	58.8%	41.2%
Combined weeks		N	17.0	0.0	5.0	1.0	15.0	3.0	231.0	3.0	10.0	11.0	76.0	23.0	1.0	0.0	0.0	1.0	105.0	166.0	11.0	12.0	0.0	1.0	471.0	221.0
		%	2.5%	0.0%	0.7%	0.1%	2.2%	0.4%	33.4%	0.4%	1.4%	1.6%	11.0%	3.3%	0.1%	0.0%	0.0%	0.1%	15.2%	24.0%	1.6%	1.7%	0.0%	0.1%	68.1%	31.9%

Appendix 6. Age composition by statistical week for chinook salmon captured in Sheep Rock and White Rock fishwheels, 1990 - 1995: males and females combined.

Table 1. Age composition by statistical week for chinook salmon captured in Sheep Rock and White Rock fishwheels, 1990: males and females combined. The value for the most frequently captured age class in each year is bolded.

			Age class									
Week ending	Statistical week		3^1	4^1	4^2	5^1	5^2	6^2	6^3	7^2	7^3	Total
7 Jul	26 - 27	n	0.0	0.0	7.0	1.0	16.0	8.0	0.0	0.0	0.0	32.0
		%	0.0%	0.0%	21.9%	3.1%	**50.0%**	25.0%	0.0%	0.0%	0.0%	100.0%
14 Jul	28	n	0.0	0.0	23.0	0.0	36.0	26.0	1.0	0.0	0.0	86.0
		%	0.0%	0.0%	26.7%	0.0%	**41.9%**	30.2%	1.2%	0.0%	0.0%	100.0%
21 Jul	29	n	0.0	2.0	89.0	2.0	96.0	76.0	1.0	6.0	1.0	273.0
		%	0.0%	0.7%	32.6%	0.7%	**35.2%**	27.8%	0.4%	2.2%	0.4%	100.0%
28 Jul	30	n	0.0	0.0	33.0	1.0	78.0	75.0	1.0	8.0	0.0	196.0
		%	0.0%	0.0%	16.8%	0.5%	**39.8%**	38.3%	0.5%	4.1%	0.0%	100.0%
04 Aug	31	n	1.0	0.0	24.0	0.0	25.0	42.0	0.0	6.0	0.0	98.0
		%	1.0%	0.0%	24.5%	0.0%	25.5%	**42.9%**	0.0%	6.1%	0.0%	100.0%
01 Sep	32 - 35	n	0.0	0.0	9.0	1.0	7.0	17.0	0.0	3.0	0.0	37.0
		%	0.0%	0.0%	24.3%	2.7%	18.9%	**45.9%**	0.0%	8.1%	0.0%	100.0%
Combined weeks												
		N	1.0	2.0	185.0	5.0	258.0	244.0	3.0	23.0	1.0	722.0
		%	0.1%	0.3%	25.6%	0.7%	**35.7%**	33.8%	0.4%	3.2%	0.1%	100.0%

Appendix 6. (cont'd)

Table 2. Age composition by statistical week for chinook salmon captured in Sheep Rock and White Rock fishwheels, 1991: males and females combined.

Week ending	Statistical week		Age class 3^1	4^1	4^2	5^1	5^2	6^1	6^2	6^3	7^2	7^3	Total
06 Jul	26-27	n	0.0	1.0	3.0	0.0	31.0	0.0	1.0	0.0	0.0	0.0	36.0
		%	0.0%	2.8%	8.3%	0.0%	86.1%	0.0%	2.8%	0.0%	0.0%	0.0%	100.0%
13 Jul	28	n	0.0	5.0	1.0	0.0	155.0	0.0	17.0	1.0	4.0	0.0	183.0
		%	0.0%	2.7%	0.5%	0.0%	84.7%	0.0%	9.3%	0.5%	2.2%	0.0%	100.0%
20 Jul	29	n	0.0	3.0	19.0	2.0	103.0	0.0	28.0	0.0	8.0	0.0	163.0
		%	0.0%	1.8%	11.7%	1.2%	63.2%	0.0%	17.2%	0.0%	4.9%	0.0%	100.0%
27 Jul	30	n	2.0	1.0	18.0	8.0	97.0	2.0	39.0	0.0	4.0	2.0	173.0
		%	1.2%	0.6%	10.4%	4.6%	56.1%	1.2%	22.5%	0.0%	2.3%	1.2%	100.0%
03 Aug	31	n	0.0	3.0	25.0	1.0	73.0	0.0	70.0	0.0	18.0	0.0	190.0
		%	0.0%	1.6%	13.2%	0.5%	38.4%	0.0%	36.8%	0.0%	9.5%	0.0%	100.0%
10 Aug	32	n	3.0	1.0	34.0	4.0	64.0	1.0	140.0	0.0	36.0	0.0	283.0
		%	1.1%	0.4%	12.0%	1.4%	22.6%	0.4%	49.5%	0.0%	12.7%	0.0%	100.0%
31 Aug	33-35	n	0.0	0.0	8.0	2.0	10.0	0.0	18.0	0.0	9.0	0.0	47.0
		%	0.0%	0.0%	17.0%	4.3%	21.3%	0.0%	38.3%	0.0%	19.1%	0.0%	100.0%
Combined weeks		N	5.0	14.0	108.0	17.0	533.0	3.0	313.0	1.0	79.0	2.0	1075.0
		%	0.5	1.3	10.0	1.6	49.6	0.3	29.1	0.1	7.3	0.2	100.0

Appendix 6. (cont'd)

Table 3. Age composition by statistical week for chinook salmon captured in Sheep Rock and White Rock fishwheels, 1992: males and females combined.

Week ending	Statistical week		Age class 3^1	4^1	4^2	5^1	5^2	6^1	6^2	6^3	7^2	7^3	Total
18 Jul	29	n	0.0	3.0	1.0	0.0	29.0	0.0	26.0	0.0	0.0	0.0	59.0
		%	0.0%	5.1%	1.7%	0.0%	49.2%	0.0%	44.1%	0.0%	0.0%	0.0%	100.0%
25 Jul	30	n	0.0	12.0	53.0	7.0	168.0	0.0	233.0	2.0	2.0	2.0	479.0
		%	0.0%	2.5%	11.1%	1.5%	35.1%	0.0%	48.6%	0.4%	0.4%	0.4%	100.0%
15 Aug	31-33	n	0.0	1.0	17.0	2.0	12.0	1.0	30.0	0.0	3.0	0.0	66.0
		%	0.0%	1.5%	25.8%	3.0%	18.2%	1.5%	45.5%	0.0%	4.5%	0.0%	100.0%
05 Sep	34-36	n	1.0	0.0	2.0	0.0	8.0	0.0	11.0	0.0	2.0	0.0	24.0
		%	4.2%	0.0%	8.3%	0.0%	33.3%	0.0%	45.8%	0.0%	8.3%	0.0%	100.0%
Combined weeks		N	1.0	16.0	73.0	9.0	217.0	1.0	300.0	2.0	7.0	2.0	628.0
		%	0.2%	2.5%	11.6%	1.4%	34.6%	0.2%	47.8%	0.3%	1.1%	0.3%	100.0%

Appendix 6. (cont'd)

Table 4. Age composition by statistical week for chinook salmon captured in Sheep Rock and White Rock fishwheels, 1993: males and females combined.

Week ending	Statistical week		Age class 3^1	3^2	4^1	4^2	5^1	5^2	5^3	6^1	6^2	6^3	7^2	Total
03 Jul	26-27	n	0.0	0.0	0.0	8.0	3.0	34.0	0.0	0.0	16.0	0.0	2.0	63.0
		%	0.0%	0.0%	0.0%	12.7%	4.8%	**54.0%**	0.0%	0.0%	25.4%	0.0%	3.2%	100.0%
10 Jul	28	n	1.0	0.0	1.0	30.0	7.0	78.0	0.0	0.0	38.0	1.0	2.0	158.0
		%	0.6%	0.0%	0.6%	19.0%	4.4%	**49.4%**	0.0%	0.0%	24.1%	0.6%	1.3%	100.0%
17 Jul	29	n	3.0	0.0	3.0	52.0	7.0	54.0	1.0	1.0	36.0	0.0	2.0	159.0
		%	1.9%	0.0%	1.9%	32.7%	4.4%	**34.0%**	0.6%	0.6%	22.6%	0.0%	1.3%	100.0%
24 Jul	30	n	1.0	0.0	2.0	34.0	8.0	51.0	0.0	4.0	39.0	0.0	5.0	144.0
		%	0.7%	0.0%	1.4%	23.6%	5.6%	**35.4%**	0.0%	2.8%	27.1%	0.0%	3.5%	100.0%
31 Jul	31	n	5.0	0.0	3.0	52.0	4.0	26.0	0.0	3.0	25.0	0.0	7.0	125.0
		%	4.0%	0.0%	2.4%	**41.6%**	3.2%	20.8%	0.0%	2.4%	20.0%	0.0%	5.6%	100.0%
07 Aug	32	n	2.0	1.0	0.0	30.0	3.0	8.0	0.0	1.0	19.0	0.0	2.0	66.0
		%	3.0%	1.5%	0.0%	**45.5%**	4.5%	12.1%	0.0%	1.5%	28.8%	0.0%	3.0%	100.0%
28 Aug	33-35	n	2.0	0.0	0.0	20.0	5.0	6.0	0.0	0.0	12.0	0.0	2.0	47.0
		%	4.3%	0.0%	0.0%	**42.6%**	10.6%	12.8%	0.0%	0.0%	25.5%	0.0%	4.3%	100.0%
Combined weeks		N	14.0	1.0	9.0	226.0	37.0	257.0	1.0	9.0	185.0	1.0	22.0	762.0
		%	1.8%	0.1%	1.2%	29.7%	4.9%	**33.7%**	0.1%	1.2%	24.3	0.1%	2.9%	100.0%

Appendix 6. (cont'd)

Table 5. Age composition by statistical week for chinook salmon captured in Sheep Rock and White Rock fishwheels, 1994: males and females combined.

Week ending	Statistical week		Age class 3^1	3^2	4^1	4^2	5^1	5^2	6^1	6^2	7^2	7^3	Total
09 Jul	26-28	n	0.0	0.0	2.0	0.0	0.0	85.0	0.0	12.0	2.0	0.0	101.0
		%	0.0%	0.0%	2.0%	0.0%	0.0%	84.2%	0.0%	11.9%	2.0%	0.0%	100.0%
16 Jul	29	n	0.0	1.0	5.0	12.0	0.0	169.0	2.0	40.0	0.0	1.0	230.0
		%	0.0%	0.4%	2.2%	5.2%	0.0%	73.5%	0.9%	17.4%	0.0%	0.4%	100.0%
23 Jul	30	n	1.0	1.0	4.0	17.0	1.0	80.0	1.0	55.0	6.0	1.0	167.0
		%	0.6%	0.6%	2.4%	10.2%	0.6%	47.9%	0.6%	32.9%	3.6%	0.6%	100.0%
30 Jul	31	n	4.0	4.0	1.0	15.0	2.0	52.0	3.0	44.0	6.0	0.0	131.0
		%	3.1%	3.1%	0.8%	11.5%	1.5%	39.7%	2.3%	33.6%	4.6%	0.0%	100.0%
06 Aug	32	n	1.0	3.0	2.0	13.0	8.0	31.0	0.0	32.0	10.0	0.0	100.0
		%	1.0%	3.0%	2.0%	13.0%	8.0%	31.0%	0.0%	32.0%	10.0%	0.0%	100.0%
13 Aug	33	n	5.0	10.0	2.0	6.0	1.0	19.0	1.0	21.0	6.0	0.0	71.0
		%	7.0%	14.1%	2.8%	8.5%	1.4%	26.8%	1.4%	29.6%	8.5%	0.0%	100.0%
10 Sep	34-37	n	0.0	4.0	1.0	4.0	3.0	5.0	1.0	9.0	3.0	0.0	30.0
		%	0.0%	13.3%	3.3%	13.3%	10.0%	16.7%	3.3%	30.0%	10.0%	0.0%	100.0%
Combined weeks													
		N	11.0	23.0	17.0	67.0	15.0	441.0	8.0	213.0	33.0	2.0	830.0
		%	1.3%	2.8%	2.0%	8.1%	1.8%	53.1%	1.0%	25.7%	4.0%	0.2%	100.0%

Appendix 6. (cont'd)

Table 6. Age composition by statistical week for chinook salmon captured in Sheep Rock and White Rock fishwheels, 1995: males and females combined.

Week ending	Statistical week		Age class 3^1	3^2	4^1	4^2	5^1	5^2	5^3	6^1	6^2	7^2	7^3	Total
08 Jul	26-27	n	1.0	0.0	2.0	8.0	0.0	10.0	0.0	0.0	12.0	3.0	0.0	36.0
		%	2.8%	0.0%	5.6%	22.2%	0.0%	27.8%	0.0%	0.0%	**33.3%**	8.3%	0.0%	100.0%
15 Jul	28	n	3.0	0.0	3.0	25.0	1.0	18.0	0.0	0.0	51.0	2.0	0.0	103.0
		%	2.9%	0.0%	2.9%	24.3%	1.0%	17.5%	0.0%	0.0%	**49.5%**	1.9%	0.0%	100.0%
22 Jul	29	n	3.0	0.0	2.0	35.0	6.0	19.0	0.0	0.0	66.0	4.0	0.0	135.0
		%	2.2%	0.0%	1.5%	25.9%	4.4%	14.1%	0.0%	0.0%	**48.9%**	3.0%	0.0%	100.0%
29 Jul	30	n	2.0	0.0	5.0	80.0	9.0	31.0	1.0	0.0	86.0	10.0	0.0	224.0
		%	0.9%	0.0%	2.2%	35.7%	4.0%	13.8%	0.4%	0.0%	**38.4%**	4.5%	0.0%	100.0%
05 Aug	31	n	7.0	3.0	4.0	68.0	4.0	19.0	0.0	1.0	41.0	3.0	1.0	151.0
		%	4.6%	2.0%	2.6%	**45.0%**	2.6%	12.6%	0.0%	0.7%	27.2%	2.0%	0.7%	100.0%
12 Aug	32	n	1.0	3.0	0.0	12.0	0.0	1.0	0.0	0.0	9.0	0.0	0.0	26.0
		%	3.8%	11.5%	0.0%	**46.2%**	0.0%	3.8%	0.0%	0.0%	34.6%	0.0%	0.0%	100.0%
02 Sep	33-35	n	0.0	0.0	2.0	6.0	1.0	1.0	0.0	0.0	6.0	1.0	0.0	17.0
		%	0.0%	0.0%	11.8%	**35.3%**	5.9%	5.9%	0.0%	0.0%	**35.3%**	5.9%	0.0%	100.0%
Combined weeks														
		N	17.0	6.0	18.0	234.0	21.0	99.0	1.0	1.0	271.0	23.0	1.0	692.0
		%	2.5%	0.9%	2.6%	33.8%	3.0%	14.3%	0.1%	0.1%	**39.2%**	3.3%	0.1%	100.0%

Appendix 7. Age composition by statistical week for chinook salmon captured in the commercial fishery, 1995: males and females combined.

Week ending	Stat. week		Age class 3^1	3^2	4^1	4^2	5^1	5^2	5^3	6^1	6^2	7^2	7^3	Total
15 Jul	28	n	0.0	0.0	0.0	13.0	0.0	18.0	0.0	0.0	47.0	7.0	0.0	85.0
		Exp	0.0	0.0	0.0	342.0	0.0	473.5	0.0	0.0	1236.4	184.1	0.0	2236.0
		%	0.0%	0.0%	0.0%	3.1%	0.0%	4.3%	0.0%	0.0%	11.2%	1.7%	0.0%	20.2%
22 Jul	29	n	0.0	0.0	0.0	21.0	0.0	55.0	0.0	0.0	212.0	8.0	0.0	296.0
		Exp	0.0	0.0	0.0	164.8	0.0	431.8	0.0	0.0	1664.5	62.8	0.0	2324.0
		%	0.0%	0.0%	0.0%	1.5%	0.0%	3.9%	0.0%	0.0%	15.1%	0.6%	0.0%	21.6%
29 Jul	30	n	0.0	0.0	0.0	19.0	0.0	25.0	0.0	0.0	213.0	27.0	1.0	284.0
		Exp	0.0	0.0	0.0	194.5	0.0	256.0	0.0	0.0	2181.0	276.5	10.2	2908.0
		%	0.0%	0.0%	0.0%	1.8%	0.0%	2.3%	0.0%	0.0%	19.7%	2.5%	0.1%	26.3%
05 Aug	31	n	0.0	0.0	0.0	57.0.0	0.0	37.0	0.0	0.0	196.0	5.0	0.0	295.0
		Exp	0.0	0.0	0.0	402.9	0.0	261.5	0.0	0.0	1385.3	35.3	0.0	2085.0
		%	0.0%	0.0%	0.0%	3.6%	0.0%	2.4%	0.0%	0.0%	12.5%	0.3%	0.0%	18.9%
12 Aug	32	n	0.0	0.0	0.0	6.0	0.0	13.0	0.0	0.0	90.0	2.0	0.0	111.0
		Exp	0.0	0.0	0.0	61.4	0.0	133.1	0.0	0.0	921.5	20.5	0.0	1136.6
		%	0.0%	0.0%	0.0%	0.6%	0.0%	1.2%	0.0%	0.0%	8.3%	0.2%	0.0%	10.3%
02 Sep	33	n	0.0	0.0	0.0	1.0	0.0	6.0	0.0	0.0	33.0	0.0	0.0	40.0
		Exp	0.0	0.0	0.0	7.1	0.0	42.4	0.0	0.0	233.2	0.0	0.0	282.7
		%	0.0%	0.0%	0.0%	0.1%	0.0%	0.4%	0.0%	0.0%	2.1%	0.0%	0.0%	0.26%
Combined weeks														
		N	0.0	0.0	0.0	117.0	0.0	154.0	0.0	0.0	791.0	49.0	1.0	1111.0
		Exp	0.0	0.0	0.0	1163.1	0.0	1530.9	0.0	0.0	7863.0	487.1	9.9	11044.0
		%	0.0%	0.0%	0.0%	10.5%	0.0%	13.9%	0.0%	0.0%	71.2%	4.4%	0.1%	100.0%

Exp = expanded by harvest.

Appendix 8. Unaged chinook salmon scale samples from Sheep Rock and White Rock fishwheels, 1990 - 1995.

Table 1. Unaged male chinook salmon scale samples from Sheep Rock and White Rock fishwheels, by year 1990 - 1995. C.V. is coefficient of variation. Legend: M1 - M5 = one to five marine years, MF = mixed fish[8], NA = not available, NP = non-preferred[9], NS = no sample, P = poor, RF = resorbed focus, RG = regenerate, RS = resorbed, S1 – S3 = one to three freshwater years, UD = upside down, W = wet.

			Unaged samples																	
Year	Wheel catch		M1	M2	M3	M4	M5	MF	NA	NP	NS	P	RF	RG	RS	S1	S2	S3	UD	W	Total
1990	1361	n	0.0	73.0	88.0	40.0	2.0	3.0	0.0	0.0	22.0	0.0	0.0	106.0	0.0	1.0	29.0	1.0	2.0	49.0	416.0
		%	0.0%	11.6%	14.0%	6.3%	0.3%	0.5%	0.0%	0.0%	3.5%	0.0%	0.0%	16.8%	0.0%	0.2%	4.6%	0.2%	0.3%	7.8%	65.9%
1991	1726	n	0.0	38.0	124.0	35.0	7.0	1.0	0.0	0.0	3.0	1.0	0.0	120.0	0.0	2.0	35.0	0.0	2.0	18.0	386.0
		%	0.0%	5.9%	19.3%	5.4%	1.1%	0.2%	0.0%	0.0%	0.5%	0.2%	0.0%	18.6%	0.0%	0.3%	5.4%	0.0%	0.3%	2.8%	59.9%
1992	1889	n	0.0	23.0	70.0	40.0	0.0	3.0	0.0	0.0	2.0	1.0	0.0	76.0	0.0	3.0	28.0	1.0	10.0	9.0	266.0
		%	0.0%	6.1%	18.5%	10.6%	0.0%	0.8%	0.0%	0.0%	0.5%	0.3%	0.0%	20.1%	0.0%	0.8%	7.4%	0.3%	2.6%	2.4%	70.2%
1993	1241	n	1.0	74.0	98.0	43.0	2.0	1.0	1.0	2.0	1.0	3.0	0.0	78.0	0.0	5.0	25.0	0.0	1.0	15.0	350.0
		%	0.2%	15.5%	20.5%	9.0%	0.4%	0.2%	0.2%	0.4%	0.2%	0.6%	0.0%	16.3%	0.0%	1.1%	5.2%	0.0%	0.2%	3.1%	73.2%
1994	1295	n	4.0	27.0	109.0	31.0	4.0	2.0	1.0	0.0	1.0	2.0	0.0	89.0	0.0	5.0	52.0	0.0	12.0	13.0	352.0
		%	0.9%	5.8%	23.6%	6.7%	0.9%	0.4%	0.2%	0.0%	0.2%	0.4%	0.0%	19.3%	0.0%	1.1%	11.3%	0.0%	2.6%	2.8%	76.2%
1995	2215	n	2.0	73.0	44.0	36.0	6.0	0.0	0.0	0.0	3.0	1.0	2.0	57.0	0.0	1.0	19.0	0.0	1.0	8.0	253.0
		%	0.5%	19.2%	11.6%	9.5%	1.6%	0.0%	0.0%	0.0%	0.8%	0.3%	0.5%	15.0%	0.0%	0.3%	5.0%	0.0%	0.3%	2.1%	66.4
Combined 1990 - 1995																					
Average			0.3	10.7	17.9	7.9	0.7	0.3	0.1	0.1	0.9	0.3	0.1	17.7	0.0	0.6	6.5	0.1	1.1	3.5	68.6
St. Dev.			0.4	5.7	4.4	2.0	0.6	0.3	0.1	0.2	1.3	0.2	0.2	2.0	0.0	0.4	2.5	0.1	1.2	2.1	5.8
C.V.			134.4%	53.5%	24.7%	25.6%	81.0%	82.0%	155.0%	244.9%	133.0%	75.2%	244.9%	11.1%	0.0%	68.2%	39.1%	162.0%	114.7%	60.7%	8.5%

[8] Scales from more than one fish taken for a given sample.
[9] Scales taken from outside of the area preferred for ageing.

Appendix 8. (cont'd)

Table 2. Unaged female chinook salmon scale samples from Sheep Rock and White Rock fishwheels, by year 1990 - 1995. C.V. is coefficient of variation. Legend: M1 - M5 = one to five marine years, MF = mixed fish[10], NA = not available, NP = non-preferred[11], NS = no sample, P = poor, RF = resorbed focus, RG = regenerate, RS = resorbed, S1 – S3 = one to three freshwater years, UD = upside down, W = wet.

Year	Wheel catch		Unaged samples M1	M2	M3	M4	M5	MF	NA	NP	NS	P	RF	RG	RS	S1	S2	S3	UD	W	Total
1990	1361	n	0.0	2.0	18.0	72.0	14.0	0.0	0.0	0.0	1.0	0.0	0.0	73.0	1.0	0.0	8.0	0.0	0.0	26.0	215.0
		%	0.0%	0.3%	2.9%	11.4%	2.2%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	11.6%	0.2%	0.0%	1.3%	0.0%	0.0%	4.1%	34.1%
1991	1726	n	0.0	2.0	59.0	70.0	12.0	1.0	1.0	0.0	2.0	0.0	0.0	69.0	0.0	0.0	28.0	0.0	1.0	13.0	258.0
		%	0.0%	0.3%	9.2%	10.9%	1.9%	0.2%	0.2%	0.0%	0.3%	0.0%	0.0%	10.7%	0.0%	0.0%	4.3%	0.0%	0.2%	2.0%	40.1%
1992	1889	n	0.0	4.0	10.0	49.0	2.0	0.0	0.0	0.0	3.0	0.0	0.0	35.0	0.0	1.0	5.0	0.0	1.0	3.0	113.0
		%	0.0%	1.1%	2.6%	12.9%	0.5%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	9.2%	0.0%	0.3%	1.3%	0.0%	0.3%	0.8%	29.8%
1993	1241	n	0.0	0.0	13.0	51.0	12.0	1.0	0.0	1.0	1.0	0.0	1.0	36.0	0.0	2.0	5.0	0.0	0.0	5.0	128.0
		%	0.0%	0.0%	2.7%	10.7%	2.5%	0.2%	0.0%	0.2%	0.2%	0.0%	0.2%	7.5%	0.0%	0.4%	1.0%	0.0%	0.0%	1.0%	26.8%
1994	1295	n	0.0	0.0	12.0	35.0	12.0	1.0	0.0	0.0	0.0	0.0	0.0	42.0	0.0	0.0	6.0	0.0	0.0	2.0	110.0
		%	0.0%	0.0%	2.6%	7.6%	2.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	9.1%	0.0%	0.0%	1.3%	0.0%	0.0%	0.4%	23.8%
1995	2215	n	0.0	1.0	7.0	62.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	39.0	1.0	3.0	8.0	0.0	0.0	1.0	128.0
		%	0.0%	0.3%	1.8%	16.3%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	10.2%	0.3%	0.8%	2.1%	0.0%	0.0%	0.3%	33.6%
Combined 1990 - 1995																					
Mean			0.0	0.3	3.6	11.6	1.9	0.1	0.0	0.0	0.2	0.0	0.0	9.7	0.1	0.2	1.9	0.0	0.1	1.4	31.4
St.Dev.			0.0	0.4	2.7	2.9	0.8	0.1	0.1	0.1	0.3	0.0	0.1	1.4	0.1	0.3	1.3	0.0	0.1	1.4	5.8
C.V.			0.0%	119.4%	75.1%	24.7%	40.8%	111.7%	244.9%	244.9%	120.0%	0.0%	244.9%	14.6%	161.9%	129.7%	66.1%	0.0%	162.5%	100.2%	18.5%

[10] Scales from more than one fish taken for a given sample.
[11] Scales taken from outside of the area preferred for ageing.